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18th NATIONAL AERONAUTIC MEETING

SEPTEMBER 1930

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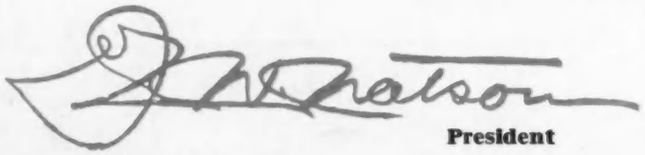

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The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

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"GUARANTEED FORGINGS"

S. A. E. JOURNAL

Vol. XXVII September, 1930 No. 3

The 18th National Aeronautic Meeting

Three Days' Sessions in Conjunction with Aeronautical Chamber and Air Races—Opens with Engine Session and Closes with Banquet

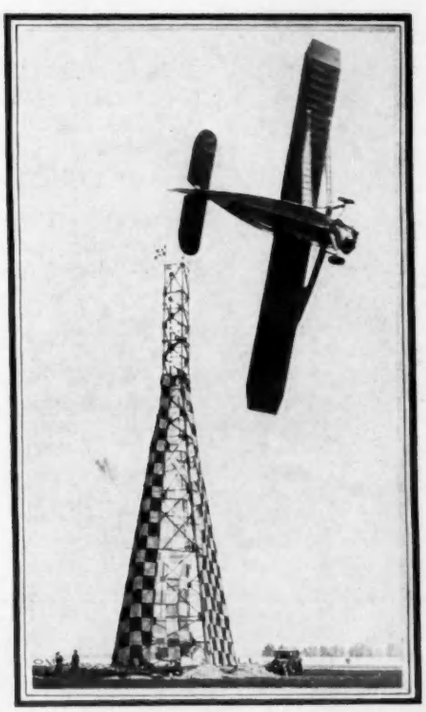
FOLLOWING three days of races, formation flying and other demonstrations at the National Air Races at the Curtiss-Wright-Reynolds Field, the 18th National Aeronautic Meeting of the Society, held jointly with the Aeronautical Chamber of Commerce of America, was opened at 10 o'clock Tuesday morning, Aug. 26, at the Palmer House in Chicago with an attendance that filled the dining room in which the Engine Session was held. General Manager John A. C. Warner convened the session and made a short address of welcome in which he said that the meeting had been arranged expressly to please the aeronautic engineers and that the committees responsible for the program had tried to give the best they could to coincide with the engineers' ideas. In return, they would like to have suggestions and criticisms from those in attendance to assist in making their future meetings most worthwhile. He said that a lot of work is behind such a meeting, performed both by the men who prepare the papers and by the members of the Aircraft and Aircraft Engine Committees. To show the substantial character of the men who stand back of the aeronautic activities of the Society, Manager Warner read their names. He then read the program for the three days of the meeting and introduced J. H. Geisse as Chairman of the Engine Session.

Without any preliminary remarks, Chairman Geisse called on E. D. Herrick, chief engineer of the Lycoming Mfg. Co., to present the first paper, on Manufacturing Costs of Aircraft Engines.

Producing Aircraft Engines Economically

The title of the paper, said Mr. Herrick, is not truly indicative of its contents, as he had chosen rather to deal with one manufacturer's method of attacking the problem of producing an aircraft engine more economically. He mentioned that the standardization work of the Society has already done a great deal to this end, not only through the standardization of materials but also in mounting dimensions and the like.

Mr. Herrick remarked that up to about four years ago airplanes were used almost entirely for military and training purposes and that the Government was virtually the airplane manufacturers' only outlet; consequently the engines and planes were designed with military rather than commercial requirements in mind. He paid a tribute to the Government and to the pioneer manufacturers for carrying on under very adverse conditions and bringing the industry to its present state, referring to the Army, the Navy and the Department of Commerce.



A TURN AT A PYLON IN ONE OF THE NATIONAL AIR RACES

Today, continued Mr. Herrick, there are three fields of aviation: the military, the specialized transport field and the broad commercial field. Since the industry has broadened into the commercial field it has been in a state of flux because the private owner, who is undoubtedly the largest potential market, is not in a position to know what he wants. However, the manufacturers do know that he wants reliability, comfort, economy and durability.

From the time that the company Mr. Herrick represents had decided to enter the aircraft engine industry, it realized that cost is a very vital factor and has undertaken to explore every line of approach to produce an engine economically. It decided upon an engine of 200 to 225 hp. and of the air-cooled radial type, as this type has, asserted the speaker, the lowest weight per horsepower and has already met with public acceptance. The selection of this type permitted the greatest latitude in design to get reasonable weight per horsepower output at a reasonable cost.

Design and Machining Costs Studied

A very careful study of design was made to assure the desired requisites of quietness and smoothness, and it was found possible to reduce the stresses in normally highly stressed parts so that the total engine weight was not objectionable, and the manufacturer was able to eliminate very difficult machine operations. Careful analysis of machining costs balanced against the weight of each part was made so as to keep within weight limitations and yet produce the parts economically. Close contact was also maintained with manufacturing departments to avoid the necessity of special machinery and unduly expensive machining operations, a number of experienced manufacturers of certain aviation engine parts being consulted during the course of the design work. A careful selection of proved units was made during the initial design and a careful study was made to allocate these units so that

Meetings Calendar

National Meetings of the Society

Production—Oct. 7 and 8
Book-Cadillac Hotel, Detroit
Production Dinner, Oct. 8

Transportation—Oct. 22 to 24
William Penn Hotel, Pittsburgh
Transportation Dinner, Oct. 23

Annual Dinner—Jan. 8
Hotel Pennsylvania, New York City

Annual Meeting—Jan. 19 to 23
Book-Cadillac Hotel, Detroit

September Section Meetings

Baltimore Section—Sept. 24
Maryland Automobile Trade Association
Subject—Progress in Lubrication

Buffalo Section—Sept. 20
Aviation Meeting—Airport Exhibition and Dinner

Canadian Section—Sept. 17
Royal York Hotel, Toronto—7:00 P. M.
Speaker—Dr. F. C. Stanley, Raybestos-Manhattan, Inc.

Cleveland Section—Sept. 13
Golf Tournament—Aurora Country Club, Cleveland

Indiana Section—Sept. 18
Edward P. Warner, speaker

Metropolitan Section—Sept. 9
Outing to West Point Military Academy on Hudson River Day Line Steamer

New England Section—Sept. 9
Governing Board Meeting and Golf

Northern California Section—Sept. 11
Athens Athletic Club, Oakland, Calif.; Dinner 6:30 P. M.
Valves for Internal-Combustion Engines—Mause Harris, President, MacKay Austin Valve Co.
Exhaust Temperatures as Related to Air-to-Fuel Ratio—L. T. Folsom, Engineering Department, Caterpillar Tractor Co.

Northwest Section—Sept. 5
Bergonian Hotel, Seattle
Six-Wheel Trucks, by E. Favary
Motorcoaches, by H. W. Musiel

Oregon Section—Sept (?)
Subject—High-Speed Diesel Engines

Philadelphia Section—Sept. 17
Smoker—John A. C. Warner, speaker

Pittsburgh Section—Sept. 24
Pittsburgh Athletic Club; Dinner and smoker

they would be accessible for inspection and service as well as to dispose them so that the drives and attachments could be effected at the minimum cost.

Both the physical properties and the availability of the materials were carefully studied and by reducing the number of materials used it is possible to purchase them in larger quantities, which is a vital factor in obtaining special materials and also simplifies the heat-treating equipment, inspection and metallurgical work.

Parts Makers' Experience Utilized

Following completion of the design work, an extensive program of experimental and development work was undertaken in the factory laboratory and in flight, which resulted in design weaknesses being corrected and new schemes tried in an effort to reduce the cost of the parts. A number of manufacturers of parts who are specialists on these parts and can manufacture them more cheaply than they could be produced in the engine manufacturer's own plant were selected as sources of supply, which obviated the necessity for the purchase of machine-tools for those parts. The knowledge of these parts makers was drawn upon in many cases to help in designing specific parts for economical production and also in the selection of suitable materials that are obtainable within a reasonable time. This availability of materials is of the greatest importance.

The manufacture of aviation engines by an existing company which has already manufactured a similar line such as automobile engines makes possible the utilization of the purchasing power of an organization that has had experience in a high-production field in parts similar to those used in aviation engines, particularly those from permanent-mold castings, forgings or stampings, and by purchasing in large quantities, the number of machine-tool set-ups is minimized and more elaborate tooling can be used, which brings the manufacture of aviation engines more on the basis of automobile-engine parts.

In the selection of equipment, the present state of aviation with regard to engine requirements made it necessary to consider machine-tools of a somewhat universal nature and the use of special fixtures that are removable, rather than the use of special-purpose machines. Also, experience in other lines of endeavor indicated that the use of over-size equipment was desirable to obtain the maximum trueness and good finish if production speed was to be accomplished.

More skilled mechanics are required on aviation engines than on automobile engines, primarily because of the high cost of the materials, but no reason exists why the piece-rate system cannot be used on aviation engines if recognition is given to the importance of the work. Very rigid inspection must be maintained from the raw material to the completed piece and it has been found economical to thoroughly inspect raw materials and follow through the sequence of operations so that any defective parts can be scrapped with the least amount of machine work having been done.

Too Much Inspection Duplication

Mr. Herrick stated that in the Lycoming factory as well as in other factories there is a great deal of duplication of inspection on parts that are purchased and he believes that it is feasible to procure reliable vendors who realize their moral obligations and are willing to furnish affidavits as to the

VIEW OF PART OF GRANDSTAND AND FIELD DURING THE NATIONAL AIR RACES

parts they manufacture meeting the specifications in their entirety. Either the vendor's or the purchaser's inspection should be eliminated; preferably, inspection should be maintained at the source to avoid transportation charges in the event of rejection.

In conclusion, the speaker said that there is no magic or secret formula for reducing cost on aviation engines; rather, it is the product of the application of general principles of intelligent cooperation and coordination of effort, both with outside sources of supply and within the engine builder's plant, coupled with hard work.

Chairman Geisse, in commenting upon the paper, said that he did not know anyone who was in a better position to write a paper about the cost of production than Mr. Herrick, in view of the fact that the Lycoming and the Stinson companies together have dropped their prices considerably below those of anyone else, with the hope of making money with quantity production. The speaker might have elaborated, he said, upon the advantage of buying parts from parts makers, as the one best way of decreasing cost of production is to increase the production. If the engine manufacturers can get together and agree upon some standards it will be possible to supply each of them with certain parts, and in this way accomplish a reduction in cost by quantity production that cannot be obtained in any other way at present.

Another important point is the tremendous waste by duplication of inspection, which should preferably be made at the source. If steel for forgings were inspected at the source, a few photomicrographs from a couple of test pieces would suffice on the ingot itself, and one test of the initial piece would be satisfactory, but without this test of the ingot, each piece that goes through successive operations must be separately tested, so that inspection piles up as the size of the material is reduced.

Aircraft and Automobile Engines Compared

Henry M. Crane, of the General Motors Corp., the second and last speaker, gave a talk on Comparative Data on Powerplants for Motor-Cars and Aircraft. He referred to the time almost exactly 15 years ago when the president of the Simplex Automobile Co. called upon him to go to Europe to pick out an aviation engine to build. When he arrived in Paris he was shown the Hispaño-Suiza engine, which was up for government consideration but had not passed the 50-hr. government test. The French government preferred the Peugeot engine, but, after examining the two engines, Mr. Crane and the president of the Simplex Company refused to sign a contract to build the Peugeot and said that they would take the Hispaño or none. The Peugeot Company built a lot of less than 100 and "washed out." The Hispaño was built to the extent of 45,000 by the end of the war and was the first of a very definite type, having cast-aluminum cylinders with steel liners. Mr. Crane said that it is a great tribute to the designer that he foresaw the possibilities of that design, because it has never been improved upon fundamentally for the liquid-cooled engine.

Similarity in design between the Cadillac eight-cylinder V-type engine and the Hispaño eight-cylinder V aeronautic engine was shown by superposed outline drawings and by individual drawings mounted on the blackboard easel. The 300-hp. Hispaño was built in 1918 and the Cadillac 90-hp. automobile engine was built last year.

A Cadillac engine of the same size built in 1922 or 1923 for the races at Mount Clemens, Mich., was carried to a point of delivering 420 hp. at about 2400 or 2500 r.p.m. The weights of the Cadillac and Hispaño engines are very similar, but the difference in the two types of design is fundamental because of the very different requirements.

Best Materials and Work Required

Mr. Crane said that the public almost universally prefers a heavy car at the same initial cost and is willing to pay the extra cost for fuel and tires for the greater stability and comfort. The weight of the car is supported by the road and the powerplant is not required to do that part of the job; consequently motor-cars can be built out of material of the lowest possible cost and cars weighing 2500 to 2600 lb. are being sold today at a price of less than $600. These cars are being delivered at a price per pound that is actually less than the cost of a great deal of material that is used in aviation engines.

The aviation engine is entirely different, as the supporting of the airplane in the air is primarily a matter of engine power, and the cost of the airplane must be divided between the plane itself and the powerplant, but if a pound is added to the weight of the engine it is necessary to add more wing surface to carry the weight.

Mr. Crane referred to a considerable amount of comment that he has seen regarding the extreme care used by the manufacturers of aeronautic engines and said he thought there is a disposition to attribute it to the Government departments and to say that leading engine manufacturers probably would not use the same care if they were designing and manufacturing for commercial aviation. However, he is strongly inclined to suspect that when cost of operation enters into consideration, coupled with the ability to do something useful with the over-all result, that is, to furnish real transportation, their way in general is the only way to build engines. The speaker dealt at considerable length with this phase of the subject and the importance of the utmost care in manufacture to assure accuracy and reliability.

SOME OF THE GUESTS AT THE SPEAKER'S TABLE AT THE AIRCRAFT BANQUET

(Left to Right) Vincent Bendix, Nominee for President of the Society; Igor Sikorsky, of the Sikorsky Aviation Corp., and E. W. Stewart, Chairman of the Chicago Section of the Society

Mr. Crane emphasized that the opinions he expressed were his own personal views and not those of the General Motors Corp., as some engineers, both in and outside of that corporation, disagree with them. He is not in agreement with the idea that the military engine is excellent from a military point of view but that an engine for commercial service should be designed in an entirely different way to produce greater reliability.

Reserve Power a Vital Factor

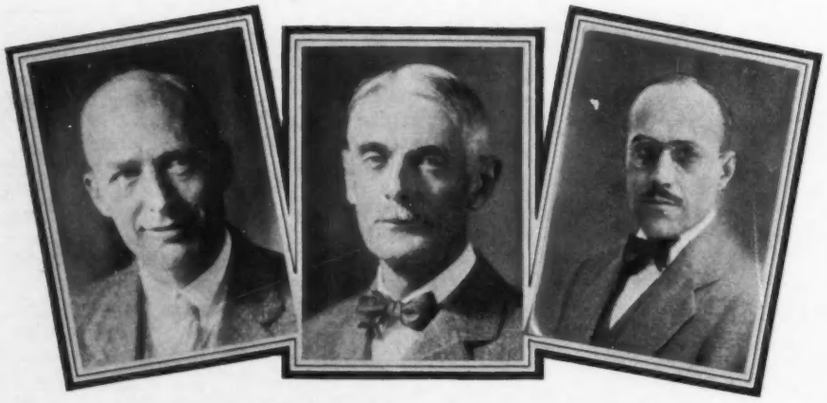
The horsepower of any engine is bound to be based on some life at full throttle, but what that life is we do not know. We do know, Mr. Crane said, that for safety reasons the aircraft engine should be run much as the automobile engine is, with a very large excess of power available. He said that C. F. Kettering's attitude in the main is that it is desirable to have aircraft powerplants capable of delivering at sea level nearly twice the actual cruising horsepower. A factor that Mr. Crane feels that we do not know is what condition the engines will be in to deliver maximum power after months of use at reduced horsepower.

The fundamental of successful operation for any length of time is absolute gas-tightness; if there is any considerable leakage of gas past the pistons or valves, overheating will inevitably result and the accumulated effect will virtually wreck an engine in a very short time. The very large cylinders of air-cooled engines are bound to change shape more or less under variation of temperature caused by difference in operation or even in speed through the air. The speaker intimated that we may even go to more cylinders and mounting them in the airplane in such a way that they do not seriously affect the performance due to head resistance or otherwise, but certainly increasing the number of cylinders will not lower the cost.

No Chance of Cheap Engines

He said that it still seems to him that no chance whatever exists of aircraft engines being built in the same quantities as the motor-car engines at anything like the same cost per horsepower. They will inevitably be built of much more expensive materials and the materials must be machined at a far higher cost and the parts must be inspected and tested much more thoroughly.

Mr. Crane made a plea for the airplane to be designed for the engine and for special attention to be given to the mounting of the engine, as the way the engine is mounted and the general structural characteristics of the plane have a great deal to do with the smoothness of operation of the engine.



CHAIRMAN AND SPEAKERS AT THE SESSION ON ENGINES

J. H. Geisse, Vice-President of the Comet Engine Corp., Chairman; H. M. Crane, Assistant to the President, General Motors Corp., and E. D. Herrick, Chief Engineer, Lycoming Engine Co., Who Presented the Two Papers

Diesel Engine Prospects Analyzed

In concluding his talk, the speaker referred to the recent development of the Diesel aircraft engine, saying that if time permitted and anyone desired to hear his personal opinions regarding it, he was willing to air them. Chairman Geisse said he was sure that the audience would be glad to hear them and the audience expressed its approval by applause. Mr. Crane analyzed this subject very carefully and at considerable length, pointing out some of the difficulties inherent in the high-speed light-weight Diesel engine, such as the very high explosion pressures, the difficulty of metering the minute quantities of oil and the difficulty of getting a good mixture of fuel and air in the very short time-period of the explosion strokes. Summing up his opinions, he said that the Diesel engine is not at all impossible, but that it is even probable in the larger units, although the most profitable field for it, which is the lighter-than-air ship, has not yet been successfully invaded.

If the compression-ignition type of engine with high explosion-pressures is designed for a reasonable degree of economy, it will be far heavier per horsepower available than the corresponding Otto-cycle engine even in its present form. It would be considerably more costly to build and require a higher degree of maintenance. If it is possible to run with considerably lower mean effective pressures than the gasoline engine, it may become comparable in other ways.

Following the conclusion of Mr. Crane's talks, there was extended discussion on both his and Mr. Herrick's addresses, which was participated in by Chairman Geisse, who did not fully agree with Mr. Crane's ideas regarding the Diesel engine; Wesley L. Smith, of the National Air Transport, who said that neither the carburetion nor the ignition systems now in use are satisfactory to commercial operators; R. H. Fletcher, formerly of the Lycoming Mfg. Co.; E. D. Herrick; H. S. Vance, of the Studebaker Corp., who raised the question of completeness of combustion in the Diesel and the Otto-cycle engines; John D. Akerman, of the University of Minnesota, who expressed the opinion that too much mystery surrounds the aviation engine and that it is killing public interest and confidence; L. B. Kimball, of the Kimball Aircraft Corp., who wanted some information on the new semi-Diesel system on which the Pratt & Whitney Co. is working; Mr. Crane, who responded on the subject of complete combustion; A. F. Denham, of *Automotive Industries*, who emphasized the importance of the cooperation of the engine and airplane manufacturers and suggested that the Society appoint a committee to work out a standard tolerance system for the aircraft-engine industry; and J. M. Royal, of the Western Electric Co., who said that a surplus of air in the Diesel makes for more complete combustion.

Flight Research and Radical Design

Advisory Committee Studies of Maneuvers and Dives Described—Stout Suggests Lines of Experiment

TUESDAY'S night session on Aeroplane Design had for its subject a prepared paper on Flight Research, by J. W. Crowley, Jr., of the National Advisory Committee for Aeronautics, and an extemporaneous talk by William B. Stout, president of the Stout Engineering Laboratories, on The Possibilities of Radical Airplane Design. Both of these proved of much interest and Mr. Stout's criticisms of present airplane design and various possible ways of improving upon it gave the attendants a great deal to think about.

A. J. Underwood introduced B. Russell Shaw as Chairman of the session in a brief statement of his accomplishments in aviation, and Mr. Shaw, with no preliminary remarks, introduced Mr. Crowley as the first speaker.

Instruments Used to Determine Flight Path

As it is out of the question to attempt to cover in one paper all of the problems of flight, Mr. Crowley confined his remarks to investigations of maneuverability and spins, describing the instruments and test methods employed by the N.A.C.A. and some of the latest results being obtained, with the purpose of pointing out the possibilities of flight research rather than presenting data of direct use. He described and showed lantern slides of the accelerometer, the turn meter and the air-speed meter. He stated that the ability to maneuver is at present based almost entirely upon individual opinions and that, therefore, the Committee has started a collection of quantitative data with respect to the maneuverability of different planes, from which it is hoped to compare the merits of the airplanes investigated and ultimately to formulate a satisfactory criterion of maneuverability and the factors that influence it.

Special attention has been given to certain maneuvers of immediate interest, particularly pulling out of dives at high speeds. The basic consideration has been to determine the flight path of the airplane and its motion along that path. By means of the instruments illustrated and described by Mr. Crowley, together with other similar instruments for more incidental information, the Committee is able to obtain a history of any maneuver similar to a loop.

In these measurements variations against time are given for the elevator, aileron and rudder movements, angular velocity, angular displacement, angular acceleration, air speed, angle of attack, normal acceleration, and longitudinal acceleration. Making use of such information, the instrument method of flight-path determination has been developed. By means of a three-component accelerometer, the accelerations along the longitudinal, transverse and normal axes of the airplane are recorded on the same photographic film and from these records the angular displacement of the airplane and the accelerations acting on it are plotted in curves of horizontal and vertical velocity against time. By integration of the various curves plotted from the instrument records the flight path is determined. This type of work requires extreme accuracy of measurement by the instruments, and the Committee is able in general, said Mr. Crowley, to determine the flight-path coordinate to approximately 5 per cent.

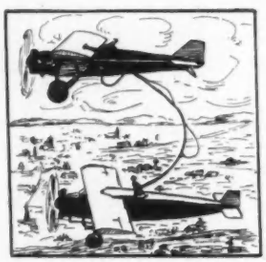
Study of Dives and Spins

The investigation of dives is being made at the request of the Navy Department, one of whose problems is to determine the loss of altitude necessary for recovery from a dive at the high speeds used for bombing. It is desirable to release the bomb at as low an altitude as possible and to recover from the dive without danger of striking the water or overstressing the airplane. Study of the dive data already obtained has made it possible to construct a chart showing the relations between altitude loss, acceleration and air speed. The interval of time that a reasonably high value of acceleration is experienced is of interest, since experience has shown that a pilot is more affected by a moderately high acceleration maintained for a considerable time than by a very high acceleration for a very short time.

The Committee discovered that to obtain any dependable information regarding the quantitative character of the motion and forces of an airplane in a spin, it was necessary to go to full scale, and the Committee has developed a method by means of which all the elements of a fully developed spin can be determined. It has also devised a method for investigating the motion and forces acting in the entry and recovery from a spin. By measurement from the angular velocity about three

reference axes, accelerations along these axes and the vertical velocity of the airplane, it is possible to determine the flight path in a spin and the motion of the airplane along this path.

Another method has been developed for accurately determining the mass distribution of airplanes, and from this and the motion the mass forces and moments acting during the spin can be ascertained. The Committee is now in the process of determining the effect of change of mass distribution, balance and wing loading on the spinning characteristics of a training-type airplane. The results of these investigations have not yet been worked out but the Committee intends to continue the investigations on spinning with an airplane that has been reported on several occasions as being very difficult to recover from a spin.



Mr. Crowley remarked that it is interesting to note that the radius of gyration in a spin is surprisingly small, hardly ever exceeding 10 ft.

Answering several questions asked in the discussion on the paper, Mr. Crowley stated that all of the instruments are damped by means of a small oil dash-pot and that in a spin the mean angle of attack over the whole wing has been found to be 48 and 49 deg.

Medal for Courage Presented

Before introducing Mr. Stout as the second speaker, Chairman Shaw called to the platform P. E. Cook, vice-president and general manager of the Stout Engineering Laboratories, and explained that he had just made a flight with Mr. Stout from Detroit and landed in Chicago the preceding night, and that the meeting would like to present him with a medal in recognition of his courage in flying with Bill Stout. He thereupon pinned a 7-in.-diameter paper medal on Mr. Cook's chest.

In introducing Mr. Stout, the Chairman remarked that he had done a great many things in aviation and airplane design that others feared to do and that he now has his own engineering laboratory and believes that because the airplane has been built in a certain way is no reason that that way is right. He said that Mr. Stout has done what a great many would like to do but lacked the nerve, and that is to develop and build a type of airplane that we will undoubtedly see in the future and to carry it forward and make it a practical machine.

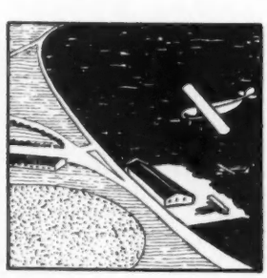
Must Develop Better Airplanes

The subject of his paper, remarked Mr. Stout, left the door wide open for him to say almost anything on the subject of airplanes, aircraft experimentation and manufacture. Before airplane makers can get out of red ink, they must build an airplane for the private owner, which means that we must place in a hat the basic practices that have been developed, shake them up and see if we cannot utilize them in a kind of airplane that we must have before we can really call aviation an industry.

We have not made progress in airplane engineering as have other industries, asserted the speaker; we have been trying to live on our inventory instead of our brains. A lot of excellent airplanes were to be seen out at the National Air Races, he said, but the crowd was interested in the "flying egg-beaters" that land in a 150-ft. circle, in the Waterman machine, in the flexible machine and in any new idea that promises something better. The engineer may laugh at such things and say that they are wrong, but the place to get your viewpoint is in the grandstand among the people who are going to buy airplanes. The public wants a machine that will land in nothing flat, and engineers can talk until they are black in the face but the public will not believe them.

Commercial Value of Speed

Another commercial aspect is presented by airline operation. The Stout Air Services figure that if they could increase the speed of a tri-motor transport by 5 m.p.h. they could save $150 a day, and they have succeeded in increasing the cruising speed from 105 to 128 m.p.h. with the same engine speed and increasing the top speed from less than 130 to more than 155 m.p.h. with the same engine and gasoline consumption. On a basis of $6 per hr. depreciation on one engine, this increased speed represents a saving of nearly 1½ hr. on three engines on a trip from Detroit to Chicago. Eight trips a day are made on this route, which means that about $600 per day is saved in operation. Moreover, it gives the passenger a quicker and better trip and probably will even enable the airplane to make one more trip per day.



Mr. Stout predicted that commercial airplanes of the near future will cruise at 200 m.p.h. with passengers, so that they will be very little affected by the winds and that this Country will not take up right away the German idea of 100-passenger airplanes cruising at a loafing speed.

Mr. Stout did not venture to tell how the problems involved can be solved but outlined a number of things that have not been tried and which are obvious. For instance, the engines and passengers could be put inside the wing to reduce wind resistance. It is obvious assininity to put the engines out in the air; if Gar Wood put his boat engines out in the water we would send him to the asylum, yet we talk about 200 m.p.h. "when the air is as thick as water."

On a wind-tunnel model exhibited at Langley Field, the National Advisory Committee for Aeronautics put a cowling and increased the speed by 12 m.p.h. Then a smooth nose was put on and the speed increased 20 m.p.h. more than with the cowling. But endeavoring to reduce the air resistance by improved cowling is simply trying to correct the mistake of putting the engine cylinders out in the air. If we put engines inside the wing and have an internal cooling system, we shall increase the weight, but for every pound of resistance saved on a good type of airplane, we can increase the lift by at least 15 lb., continued Mr. Stout. A square foot of resistance is equivalent to 450 lb. of weight in a ship, and as we go to higher speed it may be even a little more. With speeds around 200 or 250 m.p.h., every square inch of flat plate area means about 1 hp. If we can cut the area down, we can put more weight inside. It is perfectly obvious that the flying wing is the thing, declared Mr. Stout, but nobody yet knows how to build one.

Referring to the pusher type of airplane of the early days, the speaker said that if we put engineering into them today they would do things that none of our present ships will do and possibly for private ownership that type of airplane may have a place.

Obviously Wrong Things We Do

One obvious thing that is wrong is that we have a heat engine and put on a radiator to dissipate the heat; the only reason we do so is because nobody knows any better way. Again, we put an airplane tail at the back. Suppose that weighs 100 lb. and that we put a down load on it to get the angle of attack upon the wing in front. That represents a load of 200 lb. pushing down. To lift that 200 lb. it is necessary to have additional wing area with its increased drag. If the tail were put in front it would lift its own weight, and more, to give the desired angle of attack. The problems are very small and largely structural to accomplish a design like that, and it will give a chance for the pusher propeller that we will never have with a tractor propeller

blowing back against the fuselage.

Mr. Stout said that he wished somebody would tell him any place on an airplane that is the right place to put a propeller. He thinks the birds and insects which flap their wings have the right idea, but he does not know anyone who can tell how they do it. The Creator, he said, put enough things in this world for us to study to give us some clews. He thinks that we shall be almost forced to adopt shaft drive and that it will not present as much of a problem as it did in the automobile, but propellers, especially metal propellers, present a problem in balance to overcome flutter.

Cannot Compromise on Structure

Two major problems are involved in design, one being aerodynamics and the other structural. We can compromise on aerodynamics but not on structure. We can design wings that are bigger and thicker, but the problem is to build them so that they will be strong enough. Although we think of new alloys in this connection, the improvement in structure will come from finesse of design, according to the speaker, who thinks that we are coming to a stage when we are going to use more steel and do more special types of fabrication to give greater accuracy of structure.

One of the great mistakes of the industry, believes Mr. Stout, is that it has tried to make a cheap airplane. The public wants to buy the very best airplane that can be built but sold at a low price because of quantity production. If an airplane that the public wants is built, any price can be put on it and it will sell. The man to whom money is no object will buy it tomorrow, but he will not spend six weeks learning to fly and does not want a chauffeur to drive him around. Mr. Stout said he agreed with Mr. Parlin's analysis in the *Saturday Evening Post* that an immediate market exists for 100,000 airplanes a year of the type that any man can fly, but he said he would double the figures.

One of the most wholesome things about the air meet in Chicago during the week, in Mr. Stout's estimation, is that nobody is laughing at the new things as they did a year ago. The Autogiro is being taken seriously because it will do things that no other airplane will do. McDonald and Waterman have also done new things with their machines. The whole field is wide open. The slump that occurred in the industry is the best thing that ever happened to it, according to the speaker, as it has resulted in a lot of new research work; and, when this period of recuperation is over, the airplane business will be on a footing far ahead of anything that has gone before.

At a suggestion from Chairman Shaw that he divulge something regarding the experimental designs on which he is working, Mr. Stout said that he preferred to talk about them after they were done, but he quoted C. F. Kettering with reference to research work that "you never lay an egg with two hens." Research ideas originate in one mind and have to be carried through with that mind. This is the reason that the future of aviation is going to come out of some barn or a back-lot and some individual experimenter.

In the discussion, Garland P. Peed, Jr., asked what are the spinning characteristics of the Canard machine; without answering directly, Mr. Stout said that he sometimes thinks that we are going to too great extremes on spinning characteristics and quoted an expression by Tom Carroll that "the best way to get out of a spin is never to get into one." He told at some length about competitions of the Model Airplane League of America, in which about 400,000 boys are now enrolled, and of the remarkable flying models that some of them have built. One of the brightest of these boys in Detroit, who is 19 years of age, has been put to work in the Stout Laboratories, which is trying to develop from him a method of study of full-size airplanes in models. He has just finished a cabin monoplane model with a wing spread of about 40 in., made of tissue paper and balsa wood, with everything to scale except the propeller and weighing less than 1 oz., which flies excellently. If they want to know whether it will go into a tail-spin, all that is necessary is to throw it into one and see what it does.

Experiments with a Circular Wing

Paul Nemeth, of the Nemeth Airplane Co., of Chicago, was asked by Chairman Shaw to tell something about his circular wing. Mr. Nemeth recounted briefly how he had followed for 15 years the research work done in Europe and America and of building and trying out in the wind-tunnel models of the Autogiro. These gave him the idea of making a circular wing, mounting it on a high-speed engine and inclining it to the air pressure. The angle of inclination was varied from 2 to 50 deg., and it was found by experimentation with a model having a circular plate 1 ft. in diameter and 1/16 in. thick, that the lift was as good as with the best airfoil sections, except the U.S.-35-A.

The angle of inclination did not seem to affect the lift very much but increased the drag nearly 25 per cent. If this circular blade or wing section could be applied practically so as to get the minimum drag, and the angle of incidence could be increased to 25 or 30 deg., the plane could take off and descend at a very steep angle.

Mr. Nemeth said that he is not working to increase the lift but to decrease the drag and that his little model is free from spinning and stalling characteristics even if the wings are brought up to a 70-deg. angle. He has been working on the problem of high lift and low drag and has built a little model having virtually no tail, and asked whether this circular wing that might house everything except the propeller may not offer a solution of the airplane problem.

Weight Saving in Structure

Gassner and Hall Tell How Airplane Weight Can Be Reduced by Design Refinement

WEDNESDAY'S morning session on Airplane Design was devoted to two papers on the subject, Weight Saving by Structural Efficiency. The first paper presented, which was written by A. A. Gassner, chief engineer of the Fokker Aircraft Corp., was read in the absence of the author by Dr. George W. Lewis. The second paper was written and presented by Charles Ward Hall, president and chief engineer of the Hall-Aluminum Aircraft Corp. Mac Short, of Wichita, Kan., was scheduled on the program to act as Chairman but was unable to preside, and A. W. Mooney, also of Wichita, substituted for him.

Possible Weight Saving in Structure

Mr. Gassner's paper dealt with the general problem of structural efficiency. In a study that is to be published very shortly, it has been found that the airplane designer has no influence whatever on 35 per cent of the weight of the plane empty; that he has limited influence on 20 per cent of the weight, and on the remaining 45 per cent, represented by such structural parts as the wing, fuselage, tail surfaces, controls and landing-gear, the weight of which is entirely dependent on the skill and experience of the designer and structural engineer, a saving of 10 per cent of the structural weight can be accomplished by very careful consideration of every detail together with the basic design. Yet this 10 per cent saving will result in only a 4½ per cent reduction of the weight of the total airplane.

If 4½ per cent of the weight is

saved by structural efficiency, the payload can be increased by 13½ per cent and the plane still have the same gross weight. This means that the original payload of 2400 lb. of a 12,000-lb. plane can be increased by 320 lb. and that two additional passengers can be carried. At a passenger-mile rate of 7 cents, with an airplane having a life of 3000 flying hours at a cruising speed of 100 m.p.h., the income would be increased by fully $21,000.

Mr. Gassner listed the three characteristics of structural efficiency in airplane design as (*a*) choice of the basic structural system best suited for aerodynamics, space and wear requirements; (*b*) choice of the kind of material best suited for this chosen basic structure; and (*c*) use of the selected material in such a way that the least amount of material gives the required strength.

The requirements of the present-day transport airplanes were outlined and the many types of general airplane design were mentioned, such as monoplane, biplane and sesquiplane. When the useful load and performance of the early flying-machines had to be increased, more efficient structures had to be designed and the plank of wood that constituted the wing spar was transformed first into an I-beam by routing out at the neutral axis, then it was tapered in width and finally replaced by a built-up box spar having tapered flanges and webs. Similarly, in the field of metal construction the I section is replaced in airplane design by a light truss or by an I or U section, using for webs very light gage sheet metal with reinforcement channels.

Considerations Leading toward Efficiency

Considerations leading toward structural efficiency are to design simple, rigid structures having the material as far as possible from the neutral axis, to avoid eccentricities as much as possible, and to reduce the bending since a so-called pin-joined beam is always lighter than a beam in bending. In the preliminary design, stated the author, a homogeneous, simple, calculable system following a theoretical law should be considered. A considerable saving in weight can be obtained if a consistent and thorough system of design is carried out, giving the different parts of a correct proportion and adequate bracing.

The peculiarity of aeronautic construction has led to the introduction of shapes that are not commonly used for other construction purposes, yet the engineer does not give up but designs wings having a parabolic variation of thickness along the span, strives to give each member a manifold task and to reduce the number of members. His aim is to obtain a small number of elements taking a big load rather than a multitude of small elements taking a small load.

The author exemplified the foregoing fundamental considerations by an analysis of wing construction. Strength, he pointed out, is not the only criterion for a structure; thickness must be considered also, as an apparently safe reduction in strength may produce an unsafe reduction in stiffness. Elasticity and torsional stiffness have to be considered as of at least some importance.

One of the most important items in the selection of a basic structure is the structural analysis. It should be constantly borne in mind that substantial reductions in weight are a direct consequence of exact knowledge of the stresses in the members of an aircraft framework.

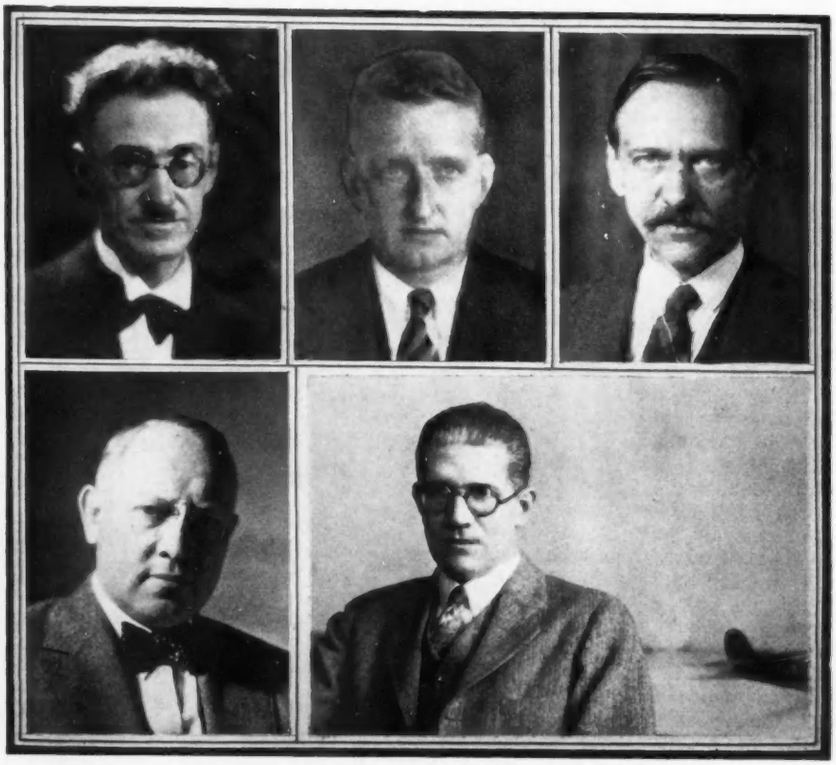
Material and Design Closely Related

In choosing the kind of material best suited for the basic structure we are somewhat freer from influences outside of the range of structure, but the selection of the basic structure and of the material best suited for it are closely interconnected. The battle between advocates of all-metal and of composite design using both metal and wood has raged for 10 years without definitely proving the superiority of either.

In conclusion, Mr. Gassner asserted that if we are to save weight we must estimate the weight of the structure closely before beginning the detailing and should also know the weight of structure of competing airplanes. Figures on weights of different wing, fuselage, landing-gear and tail-surface constructions are not available in published form. Therefore, if the designer has not kept for the use of his company a complete detailed weight record from previous planes, he is absolutely in the dark, as it is seldom possible to calculate and design in all details two or three different systems of structure for one plane that would enable calculations for all of the types to be made before selecting the all-round most efficient design.

Hall Design and Production Method

Mr. Hall's paper dealt specifically with his own methods of reducing structural weight without sacrifice of strength and was illustrated with lantern slides showing structural shapes, wing spars and numerous construction details of flying boats. Anything more than the minimum weight



THOSE WHO TOOK PRINCIPAL PARTS IN THE TWO SESSIONS ON AIRPLANE DESIGN

(Above) William B. Stout, Who Talked on Radical Airplane Design; J. W. Crowley, Jr., of the National Advisory Committee for Aeronautics, Who Gave a Paper on Flight Research; and Charles Ward Hall, of the Hall-Aluminum Aircraft Corp., Who Presented a Paper on Weight Saving by Structural Efficiency

(Below) Dr. George W. Lewis, Director of Aeronautic Research, National Advisory Committee for Aeronautics, Who Read the Paper by A. A. Gassner (Lower Right), Chief Engineer, Fokker Aircraft Corp., on Structural Efficiency

in the non-profitable loads represented by the airplane structure, the powerplant, the fuel and lubricant and the essential equipment may reasonably be taken as parasitical and should be eliminated, asserted Mr. Hall. The only one of these elements with which he dealt was the structural frame, which he divided into four general groups: (*a*) members subject to tension, (*b*) those subject to bending, (*c*) those subject to direct compression and (*d*) those subject to combined bending and compression.

To produce an airplane with maximum strength and minimum weight at a price for which it can be profitably sold, some arrangements of the parts with relation to one another and to the loads they must carry and also the selection of the best available cross-sectional forms for these parts are fundamentally necessary. The essential relation of the parts to one another and to the loads is the one whereby the load is carried but once and then directly to its final supports, that the supports shall lie approximately in a plane parallel to the load vector and also, where the loading unavoidably causes a bending moment, the support attachment must be arranged to produce a moment of contrary sign and, if possible, of the same amount. Care should also be taken to avoid secondary bending and to utilize the advantages of full continuity over any supports. Both can be accomplished in all cases through simple arrangement, asserted Mr. Hall.

Costs of construction, if equally good management, tooling and jigs are assured, are kept at the minimum by the selection of sections to which it is easy to fasten the adjoining parts, and by reducing the number of fastenings to the minimum. Wherever the design permits the use of power tools instead of hand tools for assembly, the advantages in costs are obvious. Types of section favorable to power-assembly methods are not limited to angles, open channels, I-beams and the like but include the much more structurally efficient closed hollow sections when these are designed specially to facilitate cheap connection. Numerous shapes used by Mr. Hall and riveting machines for assembling them were shown and briefly described.

Discussion of Weights and Materials

Opening the discussion, Chairman Mooney remarked that probably one of the biggest secrets in holding down the weight was pointed out by Mr. Niles and Mr. Newell in their recent book, in which they state that weight control lines in the strength of character in applying the weight control that has been figured out for whatever the type may be to the detailed design when it starts overweight by throwing the design out and starting again.

Edward Wallace, of the Great Lakes Aircraft Corp., started a debate on weight per square foot of wings by asking what is the lightest weight that Mr. Hall predicted for fabric-covered tapered and straight wings. Mr. Hall replied that there is not necessarily much difference and that he thinks the difference does not exceed 10 per cent. He has built wings for 10,000-lb. planes with a weight as low as 0.92 lb. per sq. ft. and has never exceeded 1.125 lb. per sq. ft. He agreed with Mr. Gassner that the more the aspect ratio is increased the greater is the tendency to increase the weight. On the other hand, he disagreed with him that the larger the airplane is the heavier it is necessarily per unit of wing area. Chairman Mooney inquired what is regarded as average good weight per square foot of a full-cantilever wing of conventional construction, as that is a detail about which least is known. Mr. Wallace stated that tests of tapered wings are being conducted at Wright Field with various types of structure. Some of these that are covered with metal run to 1.75 lb. per sq. ft. He said that it seems possible with duralumin construction and fabric covering to attain a weight of 1.10 lb. per sq. ft. with a tapered section.

Garland P. Peed, Jr., asked Mr. Hall what can be expected from berillium alloy, to which Mr. Hall replied that it looks very interesting from a laboratory point of view but cannot come into commercial use until the price is reduced. Answering a further question by Mr. Wallace as to whether cold-worked 17 S.R.T. aluminum alloy, at a lower cost and lower weight, would be more economical to use than 17 S.T., he said that one serious objection to the R.T. material for use around salt water is that it is much more susceptible to corrosion.

John D. Akerman, of the University of Michigan, asked how stainless-steel construction would compare with dural metal covered with two coats of paint. Mr. Hall answered that he had had no experience with stainless steel in salt water but it would have to be about only one-third as thick as dural for the same weight or reinforcements would have to be three times as close together. He has had the best success with a very thin coat of hard grease like Simoniz. Mr. Peed mentioned that he had had very interesting results from a series of tests of very thin Bakelite applied directly by means of countersunk screws to the wood stringers of a 2-ft. square test-section of a flying-boat hull. As the material cannot corrode, no paint was needed and the bottom was very slippery so that it slid through the water easily. Chairman Mooney announced that this material has been used for leading-edge covers under cloth and in several other places.

Spinning Characteristics Under Study

Investigators Present a Symposium on This Difficult Subject and Show Motion Pictures

ONE of the most interesting sessions of the meeting was that of Wednesday evening on Spinning Characteristics and Control, presided over by Valentine Gephart, of Seattle, Wash., who substituted for Dr. George W. Lewis, director of aeronautic research for the National Advisory Committee for Aeronautics, who was unexpectedly called back to Washington. Short papers on the subject were presented by Lieut. Carl B. Harper, U. S. N., retired; Paul E. Hovgard, of the Keystone Aircraft Corp.; Garland P. Peed, Jr., aeronautic engineer of New York City; Temple Joyce, of the Berliner-Joyce Aircraft Corp.; Harry A. Sutton, of the Aviation Corp.; and Fred E. Weick, of the National Advisory Committee for Aeronautics.

The topic was covered so fully by the speakers and so much time was devoted to the showing of motion pictures of airplane spins that nobody seemed disposed to start a discussion afterward and the session was adjourned at 10.45 p.m.

Lieutenant Harper recounted experiences with spins and told of the phenomena developed and the loss of control and reversal of control. He classified spins as normal, or controlled, and vicious, or uncontrolled, and subdivided these into slow, fast and spiral, and flat and peculiar. Examples of the various types were given. In military training, he said, the spin should be practised so that a pilot will learn what to do and not be bewildered if he falls into a spin, but as a maneuver the spin should not be countenanced. Too many desirable flying qualities in an airplane must be sacrificed to assure normal spinning. The inherited instinct to dodge objects to save oneself cannot be overcome readily, yet a pilot must reverse his normal actions and disobey his instincts in order to come out of a bad spin, all at a time of emergency when the time for thinking is very short. He must nose down into an obstruction in case his engine quits rather than pull up over or go around it.

Designers must make use of the wind-tunnel to investigate spinning

(*Continued on p.* 369)

Chronicle and Comment

Time Schedule for Sessions

THE APPORTIONMENT of time at technical sessions was a question of intense interest to the Meetings Committee at its meeting at French Lick last May. Members of the committee pointed out that often one author will consume too much time in the presentation of his paper, to the detriment of others who have papers scheduled for the same session or leaving an inadequate period for discussion. The Meetings Committee registered its belief that each author should be told, preferably when invited to prepare the paper, how much time he would have in which to present his paper and that he should be held strictly to the designated time allowance.

The Passenger-Car Activity Committee, at its meeting in Detroit in July, looked even more closely into the desirability of making more time available for discussion by putting the delivery of papers upon a strict time schedule. This Committee decided, therefore, that at the passenger-car sessions at the next Annual Meeting each paper should be very exactly timed. Not only will an author be told how many minutes he will have for the presentation of his paper, but each paper will be scheduled definitely as to starting and ending time.

Unquestionably, improvement could be made in the technical sessions by strict adherence to schedule, beginning and ending on time. If the other Professional Activities adopt the procedure proposed by the Passenger-Car Activity Committee, it seems probable that the intent of the Meetings Committee will be accomplished and a distinct advance made.

E. S. Marks Nominated for Vice-President

TO FILL the office of Vice-President representing Passenger-Car Engineering, for which John A. C. Warner, since appointed Secretary and General Manager, was nominated prior to the Summer Meeting last May, E. S. Marks, of the H. H. Franklin Mfg. Co., has been nominated and accepted the nomination. Mr. Marks was the unanimous choice of the Nominating Committee of the Passenger-Car Activity, of which Walter C. Keys is chairman and W. J. Davidson, T. J. Litle, Jr., and H. T. Woolson are members.

Mr. Marks has been a member of the Society since 1922, is a member of the Buffalo Section and has been active in Society work.

Governors for Motorcoaches in India

EQUIPMENT of motorcoaches with suitable governors that can be sealed after adjustments have been made is urged in a communication to the Society from the assistant superintendent of the motor section of the Government Industrial Institute at Madura, India. A great market for motorcoaches exists in southern India, he writes. Most of those in use are of less than 22-passenger capacity. They are not provided with governor control and the drivers operate them without regard to speed regulations, as a consequence of which numerous accidents occur. In the interest of safety, it is suggested that local agents of American companies be instructed to install speed governors.

East-West Coast Member Contacts

MEMBERS of the Society on the Pacific Coast are desirous of forming closer acquaintanceship with executives and engineers in the automotive industry in the East and, through them, of keeping more closely informed regarding developments in the industry in the Eastern States. Mutual benefits are sure to result from frequent and closer contacts of Eastern and Western members, and interest will be added to Section meetings if visitors from distant parts of the Country will give informal 10 or 15-min. talks regarding conditions or recent developments in their territories. Members contemplating making trips to Western States are invited to notify the Society's Director of Section Activities, at 29 West 39th Street, New York City, and to forward their itineraries to him. Such information will then be made available to officers of the Western Sections and leading men in the industry in the West so that invitations can be extended to attend Section Meetings or visit individual officers and members. Western members coming East are invited to do the same.

L. R. Buckendale Nominated for Vice-President

THE Nominating Committee of the Motorcoach and Motor-Truck Activity of the Society has named L. R. Buckendale, executive engineer of the Timken-Detroit Axle Co., as nominee for Vice-President of the Activity and Chairman of its Committee for 1931. Mr. Buckendale was elected a Member of the Society in December, 1918. He was successively draftsman, designer and engineer of the Timken-Detroit Axle Co., before the World War, during which he was a captain in the engineering division of the Ordnance Department of the United States Army. At the close of the conflict he returned to the Company with which he is at present connected. He first served as a member of the Axle and Wheels Division of the Standards Committee in 1923. He served as Vice-Chairman of the Division in 1926 and as Chairman in 1927 and 1928. Mr. Buckendale has also presented two important technical papers before the Society bearing on the construction of motorcoach and motor-truck drives.

Roster Revision Blanks Mailed

BLANKS for recording changes of position and address for use in revising the S.A.E. Membership Roster were mailed to all members the last week in August. If members who have made changes in their professional connection, in their position with their organization or their business or mail address as given in the 1930 Roster will enter the correct present details on the blanks and return them promptly to the office of the Society, the work of revising the Roster will be considerably expedited. This will result in a somewhat earlier issuance of the Roster after Jan. 1, 1931.

Members making any changes between now and Jan. 1, 1931, or after returning the revision blank, are urged to notify the Society promptly to assure inclusion of their correct connection, title and address in the 1931 Roster. Those failing to receive their revision blanks should communicate promptly with the Society office.

The Autogiro Analyzed

Metropolitan Aeronautic Meeting Paper

By W. Laurence Le Page[1]

Without attempting to give a complete mathematical analysis of the forces and principles involved in the Autogiro, the author presents a brief history of its development and sets forth an elementary theory of the flight of this type of aircraft. He says that the idea of a lifting system comprising a freely rotating windmill was not original with Juan de la Cierva, but that he was the first to make a comprehensive engineering study of it and to face the problem of asymmetry of lift resulting from the difference in relative air speed on the two sides of the windmill during forward motion of the craft.

A basic feature of Señor de la Cierva's development is the free mounting of the windmill blades on horizontal hinges at the hub. When rotating, the blades are subject to the action of centrifugal force and the lift due to their passage through the air. This results in their assuming continually shifting positions, pointing somewhat upward and at different angles on the two sides of the hub as viewed from the front. The mast upon which the hub is mounted generally is set slightly to one side, to correct for the lack of symmetry.

The centrifugal force on each blade of a 2000-lb. Autogiro is said to be about 5000 lb. at 150 r.p.m., so that the inertia forces are approximately 10 times the lift forces, there being four blades. In the latest models, the blades are allowed a restricted motion in the path of their rotation, controlled by interblade bracing-cables having shock-absorbers, to relieve certain unbalanced forces that occur periodically during the cycle.

While the machine has a maximum angle of incidence for maximum lift, an angle of attack beyond this does not result in a stall. The climbing speed is not claimed to be as good as that for an equivalent airplane, but the angle of climb is said to be greatly superior. Recent progress made in the development of the type includes improved blade-sections which permit easier starting of the rotor system on the ground, so that the cumbersome double-surface tail-plane is no longer required.

In answer to questions, the author says that vertical descent in the Autogiro is possible from any altitude, but visibility and control are much better if the landing is made with some forward motion. The stability is said to be very good, but little flying has so far been done under conditions of poor visibility.

IN PRESENTING to the Society this discussion of the Autogiro, I am moved by a sincere and great respect for Señor Juan de la Cierva, the inventor of this type of aircraft. While the principles governing the flight of the Autogiro are basically fundamental, it is impossible for one to indulge in an extensive study of these principles without becoming deeply imbued with admiration for the untiring efforts of this distinguished Spanish engineer who, in the face of tremendous technical and material obstacles, has succeeded in making practical a form of flight which in due time is destined to revolutionize present methods of air travel.

In 1919 Señor de la Cierva first began experimenting with the idea of a windmill lifting-system rotating freely about a vertical or nearly vertical axis under the influence of the vertical component of the relative wind created by forward motion. Though not basically new, credit is due Señor de la Cierva for the only comprehensive engineering study of the idea of the windmill lifting-system. He, too, was faced with the serious problem of the asymmetry of lift on the windmill due to the differences in relative wind on the port and starboard sides of the system, resulting from the fact that on one side the individual blades of the windmill move into the relative wind while, on the other side, they travel with the relative wind.

Cierva's first solution of the foregoing problem was not successful, but it led him to the invention of the fundamental characteristic of his Autogiro. While the use of two windmill systems mounted concentrically one above the other on a common shaft and designed to rotate in opposite directions was originally proposed and tried out as a solution to the lack of symmetry in the resultant lift of a single windmill, this did not prove satisfactory owing to the interference effect which caused the lower windmill to turn at a speed of only about two-thirds that expected. Thus, the unbalanced lift-forces were not corrected, and other means were sought.

Study of the blade-element theory of air screws led to the realization that increased lift resulting from greater relative air speed could be compensated by decreased effective angle of incidence and that, by applying this interrelationship between velocity and angle of incidence to geometrically opposite blades in a windmill

[1] M.S.A.E.—Kellett Aircraft Corp., Philadelphia.

FIG. 1—THE FIRST AUTOGIRO FLOWN IN AMERICA

This Machine Was Brought from England and Flown by Harold Pitcairn in December, 1928. The Whirlwind J-5 Engine Was of 225 Hp.

system, centralization of the resultant lift-reaction for the whole system could be secured. The result was Cierva's second Autogiro, which comprised a single windmill system of three blades mounted upon a standard form of airplane fuselage and tail. The incidence of each blade was controllable by the pilot. This machine failed owing to lack of torsional stiffness in the blades and, presumably, the inability of the pilot to operate satisfactorily an incidence control of this nature.

The idea of hinging the individual blades was first developed by Señor de la Cierva in 1922 and has formed the basis of his successful Autogiro development. To prove this idea, a single-windmill system of four blades was mounted freely on a vertical axis above the fuselage of the machine. The blades, instead of being rigidly attached to the hub, were mounted on horizontal hinges, giving each blade individual freedom to flap during rotation. Rubber cords were used to prevent the blades from resting on the ground or on other parts of the machine when stationary, while in flight centrifugal force kept the blades at an attitude approximately perpendicular to the axis of rotation. This form of construction, though greatly modified and improved, remains a feature of first importance in today's Autogiro. The result has been a machine of remarkable flying characteristics.

FIG. 2—THE PITCAIRN-CIERVA PCA-3 AUTOGIRO, POWERED WITH A WHIRLWIND J-6 ENGINE OF 225-HP.

Basic Principles Are Simple

Before continuing to a detailed though elementary discussion of Autogiro theory, I desire to lay particular stress upon the fact that no new and unproved principles are involved in this type of aircraft. Fundamentally, the principles upon which Autogiro flight is predicated are eminently simple and precisely similar to those same principles governing the flight of the now more conventional airplane; however, the form of application of these principles is entirely new.

It will be understood that the details of Autogiro theory, particularly as regards the fundamentals of autogyration of the rotor system, are extremely complex. I propose, however, to set forth an elementary theory which, except insofar as it neglects certain factors

FIG. 3—CIERVA TWO-PLACE AUTOGIRO OF C-19 TYPE POWERED WITH AN ARMSTRONG-SIDDELEY GENET ENGINE OF 85 TO 100 HP.

which are essential in actual design-calculations, is satisfactory in conveying a general understanding of the operation of a freely rotating windmill as a lifting system. That a clear understanding of the general appearance of the Cierva Autogiro may be had, Figs. 1 to 4 show some current machines. The four-blade rotor-system is mounted on a ball-thrust-bearing hub in such a way that the whole system is free to rotate without power. No power is used to drive the rotor system of an Autogiro.

The blades of American machines are designed to rotate in a counter-clockwise direction as viewed from above, to counteract the effect of the engine torque. In flight, they turn at a speed which, for present machines, varies between approximately 120 and 160 r.p.m.; however, for any given machine, the speed of rotation is almost constant for all flying conditions. The blades are individually articulated at the hub by means of horizontal hinges at their roots, as indicated in Fig. 4, so that each blade is free to flap and is restricted only in the downward direction by droop cables which prevent the blades from resting on the ground or striking other parts of the machine while stationary. In flight, these cables are slack.

Analysis of Forces Made

In Fig. 5, the forces acting upon a rotor blade in steady flight are shown. It has been said that the blades of the Autogiro turn in the wrong direction but, while it is true that a preliminary glance might lead to the assumption that the direction of rotation will be similar to that of a wind-driven fan, a more careful study will prove the contrary. In Fig. 5, the axis of rotation is indicated and the relative wind V, caused by the rotational velocity of the blade—which is assumed—and the translation speed of the machine, is shown. The blade has an angle of pitch θ referred to the perpendicular to the axis of rotation, and an effective angle of incidence α which includes θ and which is caused by the backward slope of the axis of rotation. There will be lift (L) and drag (D) forces on the blade, these being, respectively, perpendicular to and parallel with the relative wind.

It will be seen that the lift vector (L) makes with the parallel to the axis of rotation an angle equal to (α-θ), while the resultant force (R) slopes back from (L) through the angle whose cotangent is the L/D ratio of the section $\cot^{-1}(L/D)$ at incidence α. Thus, for autogyration, it is necessary only that:

$$[\alpha - \Theta - \cot^{-1}(L/D)] = > 0 \qquad (1)$$

Under these circumstances there will be an accelerating force acting on the rotor blade. Neglecting frictional losses, in order that the rotation thus created shall be steady, without acceleration or deceleration:

$$[\alpha - \Theta - \cot^{-1}(L/D)] = 0 \qquad (2)$$

and R now lies parallel to the axis of rotation.

Assuming that there be no angle of pitch to the blade ($\theta = 0$), the condition of steady motion becomes:

$$\alpha - \cot^{-1}(L/D) = 0 \qquad (3)$$

or,

$$\alpha = \cot^{-1}(L/D) \qquad (4)$$

In other words, for steady rotation of the system, the effective angle of incidence must equal the angle whose cotangent is the L/D ratio of the section at that angle of incidence; a condition which, for most wing sections, precludes the possibility of the blade operating at or near its maximum L/D ratio. The pitch angle θ is, therefore, made such that:

$$\Theta = \alpha - \cot^{-1}(L/D)_{max} \qquad (5)$$

In Fig. 6 values of $[\alpha - \cot^{-1}(L/D)]$ are plotted against α for a typical blade section and it will be observed that there are two values for α —which, it must be remembered, includes θ — at which the autogyration will be steady, but for only one of these will it be stable.

Suppose, for example, that there is a momentary increase in the effective angle of incidence α resulting from a slowing down of the rotary motion of the blade from some external cause. For stable motion, there must be set up an accelerating force tending to speed up the blade. Therefore, for stability, the value of $[\alpha - \cot^{-1}(L/D)]$ must increase with α. Under these conditions, for any given machine, the number of revolutions per minute of the rotor is practically constant throughout the entire range of flying speeds.

We have thus established an elementary theory which is sufficient to give a clear conception of the con-

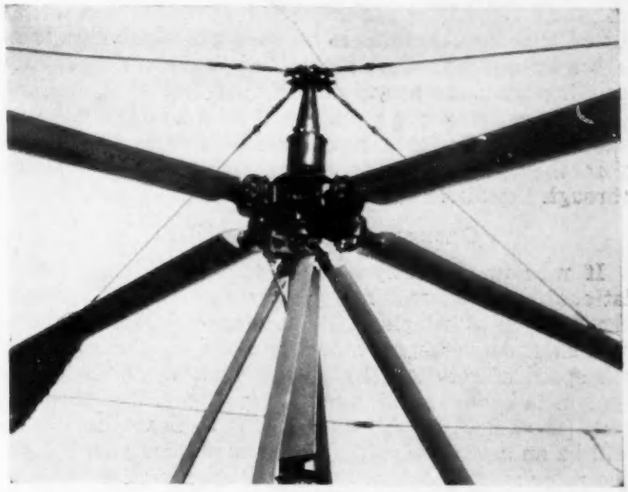


FIG. 4—A TYPICAL AUTOGIRO ROTOR-HUB EQUIPPED WITH BOTH HORIZONTAL AND VERTICAL BLADE-HINGES

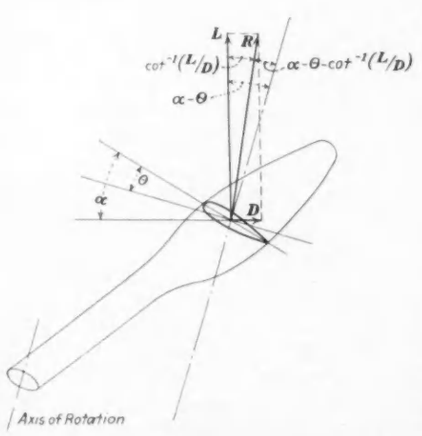


FIG. 5—FORCES ACTING UPON A ROTOR BLADE IN STEADY FLIGHT

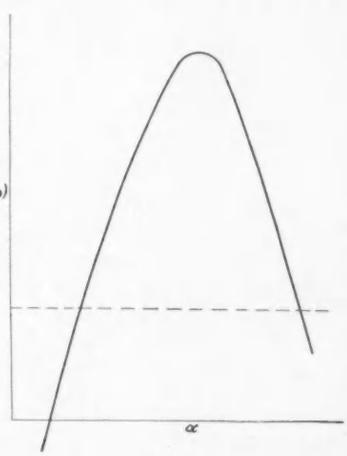


FIG. 6—VALUES OF $[\alpha - \cot^{-1}(L/D)]$ ARE PLOTTED AGAINST α FOR A TYPICAL BLADE SECTION. IT WILL BE OBSERVED THAT THERE ARE TWO VALUES FOR α— WHICH, IT MUST BE REMEMBERED, INCLUDES Θ—AT WHICH THE AUTOGYRATION WILL BE STEADY, BUT FOR ONLY ONE OF THESE WILL IT BE STABLE

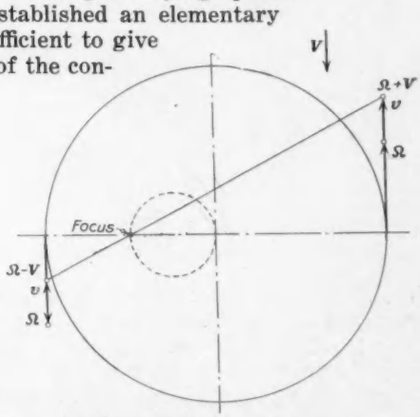


FIG. 7—IF THE SPEED OF ROTATION Ω AT A GIVEN RADIUS IN THE ROTOR SYSTEM IS EQUAL TO TWICE THE FORWARD SPEED OF TRANSLATION [$\Omega = 2V$, OR $(\Omega/V) = 2$], IT IS CLEAR THAT THERE WILL BE AN ASYMMETRY OR ABSENCE OF PROPORTIONAL LIFT ON THE ROTOR SYSTEM DUE TO THE FACT THAT, FOR ALL BLADE ELEMENTS AT THIS RADIUS, THE RESULTANT VELOCITY ON THE TWO SIDES OF THE CYCLE WITH RESPECT TO THE LINE OF FLIGHT WILL BE IN THE RELATIONSHIP OF 2:1

ditions required for autogyration. It should be remembered that the Autogiro is best considered as always in a condition of vertical descent of varying degree, depending upon the magnitude of the vertical component of the relative wind, resulting from backward slope of the axis of rotation. In other words, it is mandatory that there shall always be a component of velocity through the disc.

Outstanding Characteristics

If we now superimpose upon this condition a translational velocity, we immediately fall into difficulties, the solution of which is the outstanding characteristic of Señor de la Cierva's inventions. If, for example, the speed of rotation Ω at a given radius in the rotor system is equal to twice the forward speed of translation [$\Omega = 2\ V$, or $(\Omega/V) = 2$], it is clear that there will be an asymmetry or absence of proportional lift on the rotor system due to the fact that, for all blade elements at this radius, the resultant velocity on the two sides of the cycle with respect to the line of flight will be in the relationship of 3:1, as indicated in Fig. 7. The rotor blades are, however, free to flap about horizontal hinges at their roots, and perfect symmetry of lift is obtained at the expense of a little lateral tilting of the resultant force or thrust for the whole rotor system. The blade approaching into the relative wind is subjected to increased lift due to the increased speed and, being hinged, rises with corresponding decrease in its effective angle of attack. The blade, accordingly, operates at a lower point on the lift curve.

The reverse takes place on the opposite side of the cycle. We get, therefore, a condition of increased lift

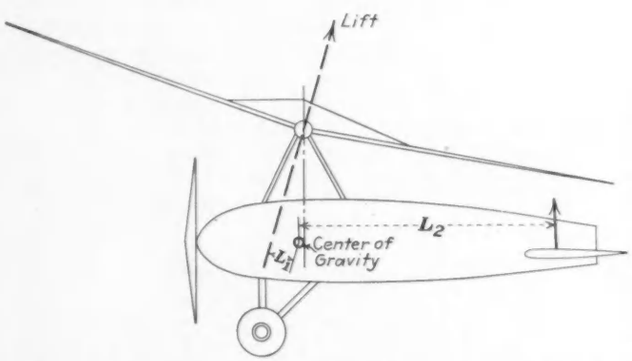


FIG. 8—LONGITUDINAL STABILITY OF THE AUTOGIRO IS COMPLICATED BY THE FACT THAT, WHILE THE ROTOR SYSTEM HAS NO CENTER-OF-PRESSURE MOVEMENT IN THE ACCEPTED SENSE BECAUSE THE THRUST REACTION ALWAYS PASSES THROUGH THE HUB CENTER, THE DIRECTION OF THIS REACTION VARIES, THE VECTOR SLOPING BACKWARD AS THE SPEED INCREASES

due to increased speed, but a lower lift-coefficient on one side and decreased speed and higher lift-coefficient on the reverse. The effect is a constant tilt of the disc of rotation when viewed along the flight path, but the lift or thrust vector passes through the hub.

It will be realized that elements of the blades at short radii stall, and that on the downwind side of the cycle certain portions of the blade will be standing still or moving backward in the relative wind. This point of zero velocity, shown in Fig. 7 and termed the "focus," is an important characteristic of the Autogiro and its position is governed by the relation Ω/V which, for efficiency, must not be less than Ω/V — 1.5. The higher the value of Ω/V is, the closer does the focus come into coincidence with the true center of rotation. This relationship fixes certain of the characteristics of a given Autogiro to obtain a required top speed, and is a controllable factor in Autogiro design. The blades of the rotor are subject to two major loads; namely, the inertia forces creating a pure tension in the members and the lift forces which are perpendicular to the former. The resultant always passes through the hinge pin because the blade is free to move until this condition exists.

In an Autogiro of about 2000-lb. weight the centrifugal force of each blade will be of the order of 5000 lb. at 150 r.p.m. Thus, the inertia forces are approximately 10 times the lift forces in each blade and the condition is that the resultant force equals $\sqrt{(10^2 + 1^2)}$, or nearly 10. An external disturbance producing 10 times the normal air-forces will create a resultant force which equals $\sqrt{(10^2 + 10^2)}$, or approximately 14.1, which is an increase of but 41 per cent over normal stresses. An increase in coning angle of the blades will result. The hub must have a designed strength plus load-factors sufficient to carry expected flight-loads, but it is clear that the problem of rotor-blade design is greatly simplified by the pure tension-load which it is expected to carry; also, the behavior of the Autogiro in bumpy air is good, since vertical disturbances are not readily passed on to the fuselage.

Other Features Outlined

In the present Cierva Autogiro, a further articulation in the rotor system is employed which permits respective blades to move in the plane of rotation relative to each other. They are restricted in this degree of freedom by loose interblade bracing-cables including shock-absorbers. The purpose of this is to relieve the blade roots of the unbalanced drag-forces which change periodically in the course of the cycle. Due also to the tipping back of the disc of rotation, other highly complex unbalanced forces are set up.

By the inclusion of vertical hinges, Señor de la Cierva has released the hub and blade roots of these lateral loads and takes them in the interblade bracing. The system has its inherent disadvantages due to its permitting masses of considerable magnitude to get into motion relative to each other, with the consequent setting up of awkward loads within the system itself. Considerable experimental work on this feature is successfully being carried out.

The precise design characteristics of the Autogiro, with the exception of the rotor system, are not very different from standard practice in conventional airplane-design. Because vertical descent is a natural and expected flight condition of the Autogiro, static balance is of great importance; also, the very wide speed-range of this machine makes it necessary to consider wide limits of aerodynamic balance and stability.

In recent Autogiros, a small fixed wing located under the rotor system has been installed. As outlined by the inventor, this is for the multiple purpose of carrying the ailerons, since control surfaces are more efficient when operating in conjunction with fixed areas; of contributing to the lateral stability, and of providing a ready and convenient mounting for the very wide under-

carriage which is necessary. The wing carries but a very small portion of the load in flight. The advisability of its use is a subject of debate.

The longitudinal stability of the Autogiro is complicated by the fact that, while the rotor system has no center-of-pressure movement in the accepted sense because the thrust reaction always passes through the hub center, the direction of this reaction varies, the vector sloping backward as the speed increases (See Fig. 8). Since the rotor is mounted high, the point of intersection of the lift vector and the center line of the ship moves forward as the speed increases, making the machine tail-heavy. The center of gravity cannot be located forward to offset this effect, since balance in vertical descent also must be considered; accordingly, a lifting tail-plane is used, which is contrary to airplane-design practice. Further, because of the high position of the center of gravity in some experimental machines, resulting from the location of the rotor system, there has been a slight power-on power-off condition which has been corrected by tilting the engine axis so that the propeller thrust-line passes through or near to the center of gravity.

Lateral stability, which is adversely affected by the low position of the lateral center of pressure with respect to the center of gravity, is achieved by giving the fixed wing a marked dihedral combined with upturned wing-tips.

The control of the Autogiro is similar to that of the airplane and, in general, the controls are equally effective; however, again because of the extremely wide speed-range, further improvements in the efficiency of controls are constantly being sought.

Autogiro Performance

Concerning the performance of the Autogiro, I desire particularly to emphasize that only conservative statements and estimates will be made. While experimental work in the further development of this type of aircraft is still in process, good performances have already been achieved.

A speed range of from zero—that is, in vertical descent at about 18 ft. per sec.—to 115 m.p.h. is possible with existing Autogiros.

Load per square foot of wing area defines for the airplane the landing-speed, and increase of top speed is inevitably accompanied by increased landing-speeds. But the landing characteristics of the Autogiro depend almost entirely upon swept-disc loading, whereas high-speed efficiency is controlled by the ratio of rotor revolutions per minute to translational velocity (Ω/V.) Rotor speed is a function of actual blade-area or of solidity, or is the ratio of blade area to swept-disc area.

Efficiency and Non-Stall Features

Señor de la Cierva has recently pointed out that the Autogiro is, for high horsepower, more efficient than the equivalent airplane at both low speeds and high speeds. He explains that if the diameter of the Autogiro equals the span of the airplane and if both have the same parasitic drag, the induced and the parasitic power required will be equal. Thus, the horsepower required in the two cases will differ only in respect to profile drag, which for the airplane is proportional to the cube of the speed; but, in the Autogiro, it varies in proportion to a much lower exponent of the speed. The curves derived from these assumptions are shown in Fig. 9 and, for the high available-horsepower condition, the speed range for the Autogiro is far superior to that for the equivalent airplane.

It would be a serious omission, in discussing Autogiro performance, to neglect mention of the non-stall characteristics of this machine. While it is true that for a given power there is a maximum angle of incidence of the rotor disc for maximum lift, the region beyond this angle does not bring with it any turbulent unstable-flow condition, nor is control of the machine lost and instability set up. The Autogiro is stable under all conditions, and excessive climb merely results in the "mushing along" of the machine.

The climbing speed of the Autogiro is, in general, not as good as for the equivalent airplane, but the angle of climb is vastly superior. While it is true that excess of horsepower is the only factor capable of giving increased angle of climb, the Autogiro secures its climb at a much lower forward speed than does the airplane.

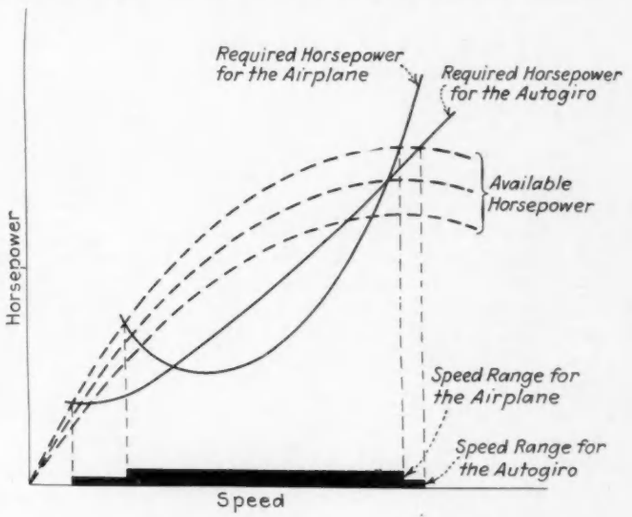


FIG. 9—HORSEPOWER RELATIONSHIP

The Autogiro Is, for High Horsepower, More Efficient Than the Equivalent Airplane at Both Low Speeds and High Speeds. If the Diameter of the Autogiro Equals the Span of the Airplane and If Both Have the Same Parasitic Drag, the Induced and the Parasitic Power Required Will Be Equal. Thus, the Horsepower Required in the Two Cases Will Differ Only in Respect to Profile Drag, Which for the Airplane Is Proportional to the Cube of the Speed; But, in the Autogiro, It Varies in Proportion to a Much Lower Exponent of the Speed

The very novel flying-characteristics of the Autogiro open up for it a tremendous future. The uncertainty regarding the human element in flying is vastly reduced. It is virtually impossible for the pilot to get the machine into a dangerous position, while a forced landing due to engine trouble assumes an aspect of secondary importance in the experience of an Autogiro pilot because of the feasibility of setting the Autogiro down within a very confined space.

Extremely rapid progress is being made in the development of this type of machine. The problem of starting the rotor system on the ground prior to take-off is virtually solved by the design of vastly more efficient blade-sections than those formerly used. As a result, the somewhat cumbersome double-surface tail-plane installed on earlier ships is no longer required.

In conclusion, I desire again to lay emphasis upon the basic soundness of fundamental Autogiro-principles, which I trust the foregoing text has set forth ade-

quately. It would be impossible at this time to attempt a discussion of those features which are in the process of greatest advancement, since the facts would be out of date ere these statements could be published. Further, the technicalities involved are in many cases extremely complex and, for this reason, I trust that allowances will be made for assumptions that have entered into the presentation of this subject.

THE DISCUSSION

QUESTION:—What airfoil section is now used for the blades?

W. LAURENCE LEPAGE:—Numerous different sections have been used for blades, and it is not feasible to discuss the characteristics of all. Within my experience, only symmetrical blade-sections have been tried out in full scale thus far.

QUESTION:—Are lead weights still being used to take up the slack?

MR. LEPAGE:—Small lead weights have been used by Señor Cierva in the interblade bracing-system to cause tension in that bracing system under flight conditions when the blades are coned up. Obviously, any bracing system between the blades will become slack in flight so long as coning is possible and the distance between the respective blades thereby decreases, even though it may be tight while on the ground. A small lead weight is used to cause the bracing cables to fly out and maintain a certain tension.

JOHN G. LEE[2]:—Regarding the vertical descent of the Autogiro, from what maximum altitude is this possible?

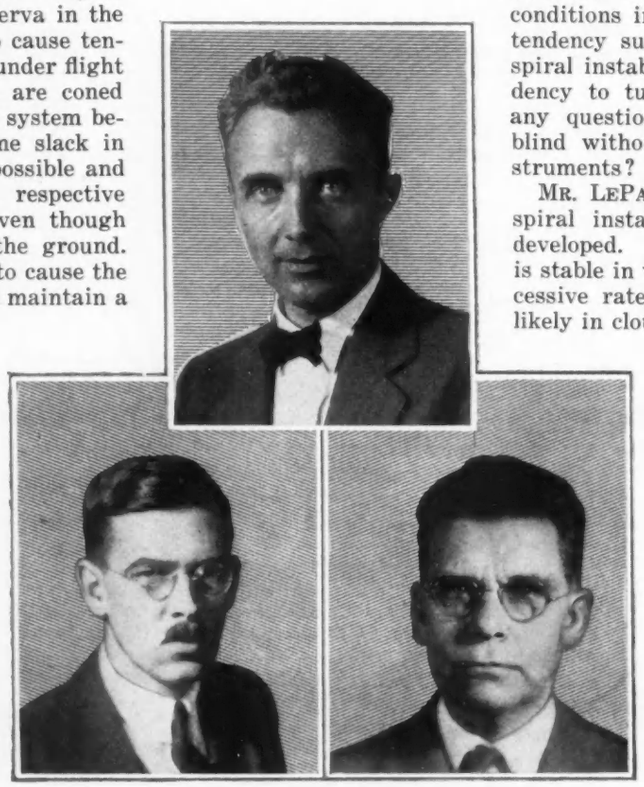
MR. LEPAGE:—Vertical descent is possible from any altitude in the Autogiro, but the advisability of wholly vertical descent is open to question. In piloting an autogiro that is descending vertically, one will find himself in a less comfortable position than if descending with a slight forward-speed that may be only a few miles per hour. In that case the pilot can at least look out at an angle of 70 or 80 deg. instead of at the uncomfortable angle of 90 deg. when looking directly downward over the side. The Autogiro is balanced statically.

C. DEF. CHANDLER[3]:—When the Autogiro is nearing the ground with the power off, I understand that there is difficulty in controlling it to reach a certain landing position and that, as it nears the ground, the tendency is to slip sideways while slowing up instead of being able to control it directly to a specified landing point.

MR. LEPAGE:—In my paper, I mention that the control of the Autogiro is subject to limitations at zero velocity, just as the control of the airplane is subject to serious limitations at low speeds. As to deficiencies in control of the Autogiro in vertical descent, these have not yet become serious and are being improved continually with improvements in control arrangements.

RALPH H. UPSON[4]:—As to handling the controls, how does the Autogiro behave under blind conditions in thick fog? Is there any tendency such as would correspond to spiral instability in an airplane or tendency to turn to one side? Is there any question about its ability to fly blind without the need of special instruments?

MR. LEPAGE:—So far as I know, no spiral instability characteristics have developed. The fact that the Autogiro is stable in vertical descent and that excessive rate of climb, which might be likely in clouds or when the visibility is poor, is not associated with any breaking-up of the airflow and its resultant stall and loss of what otherwise would be good control, indicate that there should be no serious spiral instability-characteristics when flying in poor weather. The Autogiro has not been flown extensively in fog. However, the indications are that no such characteristics exist, and it has not yet been possible for a test pilot purposely to encourage those characteristics during test flights.



RALPH H. UPSON

JOHN G. LEE A. C. WOODBURY

MR. UPSON:—It seems obvious from the general theory that the longitudinal stability should be very good. I had reference more to the direction of control; that is, the Autogiro's ability to fly reasonably straight under such conditions.

MR. LEPAGE:—Directional control is seriously curtailed when the forward velocity is zero, but there is no torque reaction from the rotor system transmitted into the machine, which has a bearing on that point.

A. C. WOODBURY[5]:—Is the axis of the rotor central with the nacelle or at one side, and are the blades of the rotor symmetrical or do the blades on one side rise higher than on the other when viewed from the front as the Autogiro is flying?

MR. LEPAGE:—Due to the flapping for the purpose of

(*Concluded on p. 310*)

[2] M.S.A.E.—Senior designing engineer, Fairchild Airplane Mfg. Co., Farmingdale, Long Island, N. Y.

[3] M.S.A.E.—Aeronautic editor, Ronald Press, City of Washington.

[4] M.S.A.E.—Aeronautical engineer, Red Bank, N. J.

[5] M.S.A.E.—Editorial department, Society of Automotive Engineers, Inc., New York City.

Airplane Dopes *and* Lacquers *and* Their Application

Wichita Section Paper

By W. W. McCUTCHEON[1]

AIRPLANE buyers today want good appearance as well as good performance, hence the finish plays an important part in the sale of an airplane. The industry has devoted considerable study to metals, wood and glue, and now must learn why finishes fail and what to do to prevent their failure. The author attempts herein to give a general knowledge of the composition, process of manufacture, and application of dopes, lacquers and pigmented dopes, and tells why trouble has been experienced with the available materials.

Simple and cheap methods of testing dope to ascertain its qualities are explained briefly, as are also the primary requisites of a good dope and the cause and remedy for "blushing," which is one of the main causes of finish failure.

Careful control of the temperature and humidity of the dope room, cleanliness and allowance of sufficient time for each coat to dry before applying the succeeding coat are essential.

The only serious hazard involved in handling the finishing materials is that of fire; there is little danger of toxic effects on the workmen, but precautions are recommended.

Pigmented dopes and colors are discussed, and the solid darker colors are recommended for durability of the finish. Aluminum is an excellent protective pigment, and the author recommends making the use of a mid-coat of this the standard practice.

In conclusion, he lists ways in which the industry can help to improve airplane finishes.

The discussion on the paper consists mainly of questions and answers relating to finishing practices and experiences.

THE SUBJECT of airplane dope and lacquer has been neglected. We know that these materials, when applied to fabric, seem to shrink it and cause it to become taut; but we do not know what the constituents are or why a finish made with them fails to withstand the service to which the airplane is subjected. We have devoted a considerable study to other materials, such as metals, wood and glue, and now we shall have to complete our knowledge of how to fabricate a complete and satisfactory airplane by learning why our finishes fail and what to do to correct this condition.

The finish plays an important part in the sale of an airplane, as the buyer of today wants good appearance as well as performance. We can hope to obtain better finishes, but to do so we must cooperate with the dope and lacquer manufacturers; and this means that we will be required to have more knowledge of this type of finish. One does not need an extensive technical knowledge of the cellulose industry, but, rather, a general knowledge of what would constitute a good dope, lacquer or pigmented dope and why we have experienced trouble with the materials available.

Years ago, glue sizing and shellac or varnish were the materials we had to use for making fabric surfaces impervious to air and moisture, but they were not very satisfactory. They were, in reality, fair-weather finishes; the dope and varnish finishes came later. Airplanes finished with clear dope and varnish were known as "clear finish," or "transparent" jobs. However, these finishes would not weather very well and the planes had to be refinished rather often. That this type of material, called dope, which, by the way, is not a slang word, would be suitable for fabric finishes was discovered through the use of collodion, which, when applied to the flesh, formed a film that was little affected by water and seemed to draw during the process of drying. The first commercial dope, resembling collodion in composition, was manufactured in France and the formula for it was purchased by a prominent English company.

Process of Dope Manufacture

Dopes, like collodion, are colloidal solutions. Collodion is made of cellulose nitrate dissolved in ether and thinned down with an alcohol, usually ethyl alcohol. Dopes are of two kinds: cellulose acetate and cellulose nitrate. Cellulose (cotton) has properties of an alcohol, and, when treated with an acid, forms an ester, which is the product of an acid and an alcohol. It is useful and of interest to note that in the majority of cases the esters end in "ate."

Cellulose acetate was, in the earlier stages of fabric finishes, the more widely used material, but the method of manufacture is complicated and makes the price of acetate dope high and its use less popular. Acetate dope will weather somewhat better and is more resistant to fire than is nitrate dope, but these advantages do not offset the greater cost of the former. Consequently, the nitrate product has gained favor in the commercial and military industry. However, the Government services specify acetate dope in the clear form in some instances.

As a result of study by the builders of military and commercial airplanes of the causes and prevention of fire following crashes in airplanes, the subsequent safer arrangement of exhaust pipes, batteries and other parts, we have little to worry about when using nitrate finishes. I shall, therefore, discuss cellulose nitrate as the universal material for use in the preparation of clear dopes, lacquers and pigmented dopes for aircraft finishing.

The process of preparing cellulose nitrate consists of treating the cellulose (cotton) with nitric acid in the presence of sulphuric acid. The acids are mixed in a

[1] Jun. S.A.E.—Materials engineer, Stearman Aircraft Co., Wichita, Kan.

dilute solution, the sulphuric acid acting in the capacity of a catalyst. A catalyst might be a chemical, heat or light, and merely tends to speed up the reaction. The sulphuric acid has no effect on the cotton, but, being of a hygroscopic nature, takes up the water formed during the operation and renders the reaction more complete. Cellulose acetate is prepared by the use of acetic acid instead of nitric acid.

Cellulose nitrate is known as soluble cotton, soluble nitrocellulose or Pyroxylin. If the reaction were carried to extremes, we should have insoluble nitrocellulose, or gun cotton.

Constituents Used and Their Purposes

To analyze the preparation of the cellulose nitrate into a fabric-finishing material, which has been christened "dope," let us investigate the constituents of dope. The following gives them in the order of their importance:

(1) Film-base compound (cellulose nitrate)
(2) Solvents
(3) Diluents
(4) Plasticizers
(5) Retarders

Film-Base Compound.—The cellulose nitrate is graded by viscosity in terms of seconds of time. This viscosity is varied by the length of time the reaction is carried out and depends on the extent to which the cotton is digested by the acid. If the reaction is cut off as soon as the change has been made from the cotton to cellulose nitrate, we have a material with a fairly long linter which, in solution, would give a high-viscosity solution; if carried far enough, we would have a short-linter cotton giving a low-viscosity solution. The method of determining the viscosity consists of making a standard solution and timing the travel of a steel ball from the top of the solution to the bottom, the container, ball, temperature and quantity to be the same in all tests.

W. W. McCUTCHEON

Solvents.—Most of the solvents are esters; however, some ketones and alcohols are used. The more important solvents for nitrocellulose are:

	Boiling-Point	
Low Boilers	Deg. Cent.	Deg. Fahr.
Ethyl acetate (anhydrous)	77	170.6
Methyl acetate	57	134.6
Ethyl alcohol (anhydrous)	78	172.4
Medium Boilers		
Butyl acetate	125	257.0
Amyl acetate (banana oil)	148	298.4
Ethyl butyrate	120	248.0
High Boilers		
Diacetone alcohol	164	327.2
Ethyl lactate	155	311.0

The low boilers have, for the most part, more agreeable odors than any other group and, in analysis, it is often necessary to trust to the characteristic odor rather than to the boiling-point to determine the identity of the solvent. The medium boilers provide flow for the dope or lacquer of which they are a part and often take the place of the high boilers, which cost more. The high boilers are the strongest solvents for nitrocellulose, and their use, when at all possible, should be made imperative. A flow diagram for the manufacture of clear and pigmented airplane dopes is shown in Fig. 1.

Diluents and Thinners.— Diluents usually are hydrocarbons and are not regarded as solvents for the cellulose nitrate. They are used for thinning the material to make volume and in preference to the solvents, as the cost of the dope or lacquer, if solvents were used entirely, would be prohibitive. These diluents also act as blending agents for nitrocellulose and certain resin solutions. However, they must not be used to excess, as they will cause the solution to gel. Some of the more important diluents are:

	Boiling-Point	
	Deg. Cent.	Deg. Fahr.
Benzene	80	176.0
Toluene	111	231.8
Xylene	143	293.0

Plasticizers.—These are incorporated in the dope or lacquer and are intended to remain in the film after the solvents and diluents have evaporated, to give the film flexibility and thereby increase its durability. If they are not of a good grade or have low boiling-points, they will also pass out of the film, leaving nothing but the cellulose nitrate. Inferior plasticizers are the cause of a large percentage of our finish failures. Some of the more important plasticizers are:

	Boiling-Point	
	Deg. Cent.	Deg. Fahr.
Tricresyl phosphate, used mainly for photographic film	350	662
Dibutyl pthalate	340	644
Diamyl pthalate	340	644

All of these are esters. Camphor is used as a plasticizer in the celluloid industry, but has not found favor in aircraft finishing. Its high volatility is possibly the greatest objection to it. It and castor oil are classed as softeners rather than plasticizers.

Retarders.—These are, in reality, solvents having extremely high boiling-points. They govern the rate of evaporation of the solution to which they are added and prevent blushing. Some of the more common retarders are:

	Boiling-Point	
	Deg. Cent.	Deg. Fahr.
Ethyl lactate	155	311
Ethyl benzoate	212	413.6
Diacetone alcohol	164	327.2

Tests for Properties of Dope

Chemical analysis of a dope consists of boiling off the various liquids and drying the cellulose to constant weight. This involves complications for which most airplane manufacturers are not equipped. However, a number of other tests, that are comparatively simple and economical to make, give considerable information about the material. The viscosity test for the cellulose nitrate has been mentioned, but to apply this to the dope it would be necessary to have a known standard of dope for comparison. This could be made a routine test and would be very helpful in checking each shipment and in showing whether the dope was at the right viscosity to be applied to the fabric.

The next test would be worked out on a panel covered with the fabric from which we could determine the workability and the filling and building qualities of the dope. These panels can be made up for exposure tests of clear dopes and pigmented materials. Such exposure panels serve as an excellent comparative test. When panel-testing, all work must be done the same day to assure that the temperature, humidity and other conditions are the same for all samples of material. A change in temperature or humidity of the room will make considerable difference in the way the material will withstand the elements. Panels about 18 in. square are very handy. Some investigators cover the panel on both sides, but it is believed that covering on one side is satisfactory, as only one side can be exposed at one time.

Methods of test on exposed panels vary. Some use the thumb-pressure method, while others use the dropped-ball test. The latter consists of dropping a 1½-in. steel ball from a height of 2 ft. onto the surface and observing the results. One dope manufacturer has recently introduced an elasticity test. This consists of testing, in tension, a strip of film after it has been subjected to accelerated weathering. If the film does not show an elongation that meets the requirements, the batch or run from which this strip was taken is set aside for reworking.

Application to the Fabric

If it has been properly formulated, the dope, when applied to the fabric, flows out well and works its way into the weave of the cloth. Assurance of the ultimate adhesion of the dope film to the fabric depends upon its ability to do this. If the dope is too thin it will not accomplish this good anchorage; and if it is too viscous, it will remain on top of the fabric and there will be no bonding of the film to the cloth.

The Air Corps states definitely that the first coat shall be brushed on lightly. The method of application is virtually the same throughout the industry, but some airplane builders are not concerned to any extent with the drying time that should be allowed for each coat. At least 45 min. should be allowed for the solvents and diluents to pass off, leaving a well-set-up film. One might say that, no matter how long the preceding coat is allowed to dry, the succeeding coat will dissolve it. To some extent this is true but, fortunately, this is desirable; the solvents should dissolve the preceding coat sufficiently so that the following coat will work into it just enough to form a bond. If the first or preceding coat is allowed to dry thoroughly, the solvents in the next coat will evaporate faster than they can penetrate, and the first coat will not be entirely dissolved. This will help us to get our build and fill with fewer coats. Four to five coats should be ample to give the desired qualities.

One of the main troubles experienced during application of the dope is "blushing." The theory advanced to explain this effect is as follows: If the latent heat of evaporation of the solvents in the dope is sufficiently high, a cooling effect is produced at the surface of the dope film, and, if the humidity of the dope room is high, this cooling causes the moisture to condense and form water. This, in turn, precipitates the cellulose nitrate out of the solution and a blush area is produced. This means that the film is not homogeneous throughout and the strength of the film at the blush is only as great as that of the precipitated cotton, which is nothing. If this condition is allowed to go unnoticed, the finish will fail at the place or places where blushing has occurred. One way of eliminating this trouble is to spray on a coat of thinner in which some retarder has been incorporated. This will redissolve the cotton and produce a continuous film that is conducive to durability.

Precautions To Observe in Handling

No danger, other than of fire, is involved in handling cellulose nitrate in the dry form or as dope or lacquer. The cellulose nitrate is shipped moist and therefore is perfectly safe. Of course, smoking must be prohibited. Sparking, caused by rubbing or sanding a wing or doped surface, should be carefully guarded against. All assemblies should be grounded before beginning to apply dope or before sanding.

Little danger of physical effects exists other than the possibility of creating an irritation of the mucous membrane. However, if the room is well ventilated this should cause little trouble. If the vapors become too concentrated, the operator should wear a nose and mouth respirator. A precaution against any toxic effects that should be given serious consideration is the drinking of milk by men in the dope room. This tends to build up the tissues of the lungs and keep them in good condition. Since the use of benzol and other harmful solvents or diluents has virtually been eliminated, no serious results from harmfulness of the vapors have been recorded of late. However, some men cannot work in a dope room at all, and care should be taken, when employing help for this purpose, to ascertain that the man is in good health.

Clean equipment is essential to assure the maximum life of a dope or lacquer. Brushes, cans and spraying equipment should be thoroughly cleaned each night. If we can remove a few faults, such as carelessness and uncleanliness, we shall have taken a step forward in finishing and will be in a much better position to criticize the materials if failure occurs when the airplane goes into service.

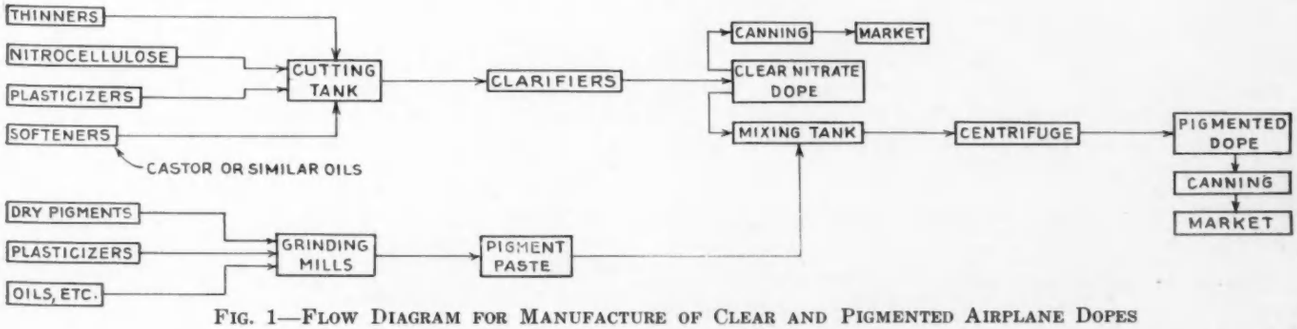


FIG. 1—FLOW DIAGRAM FOR MANUFACTURE OF CLEAR AND PIGMENTED AIRPLANE DOPES

Pigmented Dopes and Lacquers

Pigmented dopes are essentially dope solutions into which pigment has been incorporated. A true pigmented dope is devoid of all gum and therefore forms a film that presents a much more durable surface than a lacquer. The viscosity of the cotton usually is the same as for the clear dope. Many finishes on the market that are called pigmented dopes are, in reality, lacquers. A true pigmented dope, when dry, presents no gloss unless a final coat of clear dope has been applied, and this practice is not to be recommended.

Lacquers are essentially colloidal solutions, as are dopes. The viscosity of the cotton varies somewhat from that used for dopes. Lacquers contain a lower-viscosity cotton, so that more solids can be added without raising the viscosity of the final solution so high that spraying would be impossible. Cotton of ½-sec. grade is commonly used for lacquers, as compared with 15 or 20-sec. cotton for dope.

The first lacquers were manufactured with a view to producing a finish that would look like varnish, wear like a lacquer and dry rapidly. Gums were added to give the gloss finish as well as adhesion. The thought that gums had to be used for adhesion was well founded when considering the material for wood or metal varnishes, but for a fabric finish this should not have been given so much consideration, as the dope takes care of the adhesion to the fabric, and the dissolving of the surface of the dope film by the solvents of the lacquer forms a perfect bond between the two. Of course, if the solvents of the lacquer are of such a nature that they do not affect the dope film, such adhesion cannot be expected.

The presence of gum gives a hard finish to the film. This is undesirable for fabric finishes, because a constant flexing of the film occurs while the airplane is in flight, which causes the lacquer-type materials to crack or to fail in some other way. One lacquer, recently introduced, was so formulated that the solvents would not affect the dope film and the producers relied on some other constituent to give adhesion. Apparently this was insufficient, as the finish coat had no bond with the dope coat and the two were easily separated.

Choice of Pigments

Much of our present trouble with regard to pigments could be eliminated if we would be more reasonable in our choice of colors. The pastel shades, such as creams, light yellows and light blues, will not withstand service as well as the more solid colors. They are not strong pigments and consequently will break down; furthermore, they lack opacity, and the actinic, or ultra-violet, rays pass through them into the dope film, breaking down the foundation coat. When this happens, contrary to the slogan, "Save the surface and you save all," the entire finish will fail. Heavier colors, such as greens, dark yellows, oranges, some shades of red, blacks and aluminum, are quite opaque and tend to retard or stop the rays altogether, thereby protecting the base coat and the entire finish. These colors do not fade like the pastel shades. Aluminum is an excellent protective pigment and, when used as a mid-coat incorporated into the last clear dope by spraying, serves to protect the film base and acts as a unifier for the finish coat. Where sanding of the dope coat is necessary, it also serves as a sanding surfacer.

Sanding of the dope coat should be avoided when possible, as any mechanical working of the dope film does not assist it to weather as it should. I recommend making the use of this mid-coat of aluminum-pigmented dope standard practice, whether we use lacquer or pigmented dope for the finish color and whether we use the highly opaque colors or pastel shades.

The more thoroughly ground the pigment is the more hiding power we can get from the same weight of finish, and the less the pigments will settle in the container. This will assure an equal amount of pigment coming out of the gun onto the surface that is being finished.

In conclusion, we can improve or help to improve our finishes by following these recommendations:

(1) Eradicate any possible fault within the dope room that might contribute to the failure of this type of finish.
(2) Try to maintain constant humidity and temperature in the dope room. The use of an adequate system for this purpose will eventually be necessary to overcome the difficulties now being experienced, unless the finishing material is improved.
(3) Cooperate with the dope and lacquer manufacturers to the fullest extent.
(4) Advocate a finish incorporating both a pigmented dope and a lacquer, or, possibly, a modified lacquer.
(5) Inspect and test all pyroxylin materials coming into the plant.
(6) Make a study of colors or pigments and choose only those that will assist the finish. Stress the use of an aluminum undercoat.
(7) Eliminate, as far as possible, any danger of sickness or injury from the use of this type of material.

THE DISCUSSION

HERB RAWDON[2]:—Have you had any experience with Triple A?

W. W. MCCUTCHEON:—We had one panel finished with Triple A and it failed the same day it was exposed, and in one week the fabric seemed to tear by merely touching it. I was under the impression that the effect was caused by the action of the dope. Some dopes, when in contact with moisture, form acids that rot the fabric.

MR. RAWDON:—What should be the humidity of the air in the dope room?

MR. MCCUTCHEON:—It should be 60 to 70 per cent.

MR. RAWDON:—What is the effect if there is not enough moisture?

MR. MCCUTCHEON:—We never had any trouble with that condition and I do not know what it would be. Ordinarily, the humidity in our dope room is from 55 to 60 per cent and often on rather rainy days it exceeds 70 per cent. Adequate humidity and temperature control are essential.

A. W. MOONEY[3]:—I never used to pay a great deal of attention to very low humidity, but in Colorado, in the hot summer time, the finishers used to spray a slight amount of water around.

[2] M.S.A.E.—Chief engineer, Travel Air Co., Wichita, Kan.
[3] Jun. S.A.E.—President, Mooney Aircraft Corp., Wichita, Kan.

MR. MCCUTCHEON:—I have raised that question more than once with the people in the dope industry. Do you suppose the finishers were trying to take the wrinkles out of the fabric? They can be taken out by spraying water.

MR. MOONEY:—No, they did it only during the hot weather.

P. H. MACKENZIE[4]:—Do you use sufficient traps?

MR. MCCUTCHEON:—Yes, we have filter traps on the air lines and pressure tanks. We must watch these traps and free them of water or oil once a day, or leave them cracked slightly all the time.

Heat in Dope Room Prevents Blushing

CHAIRMAN MAC SHORT[5]:—In this matter of blushing, when you spray on the thinner or retarder, do you really put the cotton back in solution?

MR. MCCUTCHEON:—I would say that the retarder and thinner act on the precipitated cotton, tending to redissolve it. This is a recommended practice by manufacturers.

MR. ROBINSON[6]:—Did you ever have a case in which one color seemed to have an action on another color?

MR. MCCUTCHEON:—We never have had that. If a wing that has been painted a certain color is repainted with another color, you are likely to get too much on.

MR. MOONEY:—I know of one case in which an experiment was made to use aniline dyes and the fuselage covering came off in the air.

C. C. GIRVEN[7]:—I find that many times, if I stop all drafts, run the heat up to 100 deg. fahr., restart the drafts and continue spraying, I do away with all blushing.

MR. MCCUTCHEON:—Do you bring all the heat in before you spray the next coat?

MR. GIRVEN:—Yes, I go to work again in a few minutes.

MR. MCCUTCHEON:—You probably dry the air. The next coat would be clear and there would be no blushing, with thinner. Hot air or a hot room has rather well taken care of excessive humidity and prevented the dope from blushing. Many things remain to be done with finishing; we do not know all about it and can do much toward solving our troubles by making a thorough study of it.

MR. RAWDON:—Have you had any experience with wood finishes?

MR. MCCUTCHEON:—No.

Difficulty Encountered with Colors

CHAIRMAN SHORT:—Do you not think that one of the secrets is to unsell the sales department on automobile polish-finishes?

MR. MCCUTCHEON:—Yes, we will have to do so and we must educate the buyer regarding the more stable colors. The pastel colors are attractive, I admit, but if I were buying an airplane, I would rather have a durable finish than a flashy one that would not stand up. We can get some excellent color combinations by using stable colors.

CHAIRMAN SHORT:—Do you have any trouble, Mr. Stratton, with the fading of colors on automobile bodies?

L. H. STRATTON[8]:—Yes, with certain colors, such as a light red, some brands of which fade two weeks after being put on, while others are not so bad. We tried to cover one car that had a light-red finish with a brown finish and the red came right through six or eight coats.

CHAIRMAN SHORT:—That brings up the subject of the difficulty of matching certain colors used by the finish manufacturers. One maker's blue is not the same as another manufacturer's blue. Service-station men might have a bone to pick there.

MR. MCCUTCHEON:—It is unfortunate that the finish companies have trick names. We get a call for some such color as Garovani blue and look through our color chart and have a hard time matching it in the make of material we use.

Various Cleaners Found Satisfactory

MR. MACKENZIE:—What about cleaners? There is a patented compound that is used for washing.

MR. MCCUTCHEON:—Nothing but inert chemicals and a small percentage of abrasive should be used in a cleaner. We often water-sand our finishes. I think one of the best cleaners is Lux soap.

MR. MACKENZIE:—What is the effect of gasoline on the fabric? That seems to be the old standby.

MR. MCCUTCHEON:—I should think that the ordinary run of gasoline would be all right; higher-test gasoline might not be so good.

MR. MOONEY:—I would say that the principal objection to using gasoline as a cleaner is that it leaves a very slight coating of oil or residue.

FRANK A. DOBBE[9]:—The best soap we found at the St. Louis Aircraft Show contained just enough oil to make a fairly good luster with some "elbow grease" applied, and it does not hold the dust.

MR. GIRVEN:—Mr. McCutcheon said that he found that four or five coats was plenty. Did he not find that he had to use twice as many coats of some dopes to get the same tautness?

MR. MCCUTCHEON:—Yes, but I can get sufficient tautness and fill with four coats of our present dope. However, that depends on the proportion and viscosity of the cellulose nitrate in the dope.

MR. DOBBE:—Do you not also find a great difference in the hardness of the finish that makes a difference in the fabric?

MR. MCCUTCHEON:—I have not, but do you suppose that could be attributed to the moisture content?

MR. DOBBE:—We tried to put a minimum number of coats on gliders. I do not know whether the trouble is due to the moisture content of the fabric or the surface hardness of the cloth.

MR. MCCUTCHEON:—It is possible that one fabric may contain more sizing than another.

MR. DOBBE:—Both are supposed to be the same material and were taken from the same roll.

MR. MCCUTCHEON:—They are likely to vary or change, as other materials do.

MR. DOBBE:—We have used Triple A on gliders but are trying other fabrics.

MR. MCCUTCHEON:—Did you have success with Triple A?

MR. DOBBE:—We have rather good results with it on gliders. It does not take the body or luster for airplane finish but stands up fairly well and draws tautness on gliders.

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[4] Ground-school instructor, Central Air College, Wichita, Kan.
[5] M.S.A.E.—Vice-president, chief engineer, Stearman Aircraft Co., Wichita, Kan.
[6] Purchasing agent, Mooney Aircraft Corp., Wichita, Kan.
[7] General paint foreman, Travel Air Co., Wichita, Kan.
[8] A.S.A.E.—Service manager, Mosbacher Motor Co., Wichita, Kan.
[9] Jun. S.A.E.—Development engineer, Cessna Aircraft Co., Wichita, Kan.

Aircraft-Engine Installation

Semi-Annual Meeting Paper
Illustrated with Photographs

By ARTHUR NUTT[1]

THE PAPER urges united cooperation instead of the present division of responsibility between the engine designer and the airplane designer in the installation of aircraft engines. The tubular rings upon which engines are commonly mounted are usually supported by structural members that are welded to the ring and attached to the fuselage at the four longitudinals. Inaccuracy is common in these structures, and many of them lack sufficient stiffness.

Gravity gasoline-feed is recommended for its simplicity, provided the pressure head required by the carbureter can be secured, but the author reports having seen an installation in which the engine would operate so long as the airplane had its tail on the ground, yet the engine would die as soon as the tail was raised during a take-off. The use of gasoline-resisting rubber-hose with metal liners and the avoidance of sharp bends are recommended for the gasoline connections. A strainer of ample capacity with an accessible drain should be located near the carbureter.

The overflow from the pressure-relief valve is reported to be the cause of vapor lock sometimes, when it is merely a return to the pump inlet. The location of oil tanks often is such as to prevent effective cooling, and oil thermometers frequently are located at the engine oil-inlet instead of at the outlet. For new installations, thermometers are recommended to indicate both the inlet and outlet temperatures of the oil.

Too little attention is given to carbureter heating, the author says. The carbureter must be jacketed if warm air is not supplied in sufficient quantity to prevent the formation of ice around the jets and throttle. Other installation details that require more attention are the electric wiring, the engine controls and the cowling.

In the discussion it is stated that there has been a constant battle between the Air Corps and the manufacturers to secure uniform and adequate installations. More direct cooperation between the Department of Commerce and the Army and Navy Services is recommended because the latter have learned much that would be of great help to commercial operators. Further discussion has to do with carbureter heating and oil cooling.

THE subject of this paper was selected as it was thought that the problem of aircraft-engine installation is one which has not received as much attention during the past as it should have received, particularly from an engineering and service standpoint. Many of the failures of powerplants in the air have not been caused by engine failure, but by engine installation. It is believed that the major reason for this unfortunate condition is the lack of engineering when combining the airplane and engine. At present, engine installations are being made by aircraft designers and, while the engine engineer is often consulted regarding the installation, he is not responsible for it.

It appears that the importance of making the necessary connections from airplane to engine have not been fully realized. (See Fig. 1.) Many of the engine installations which are in operation today do not have the appearance of being well planned at the time the airplane was designed. It appears that the aircraft designer has the tendency to put the bulk of his effort into aerodynamics, rather than into the practical consideration of installation which has to do with the successful operation of that airplane. No doubt many connections on the engine could be rearranged to facilitate installation in an airplane; but, with the divided responsibility which now exists, progress toward this end is not rapid. (See Fig. 2.)

It is of prime importance, in considering the installation, that the very best reliability be obtained even at the sacrifice of weight. The second important requirement is accessibility. Inasmuch as the small air-cooled engine is the type more universally used in commercial aircraft, the installation of this type of engine will be discussed in detail.

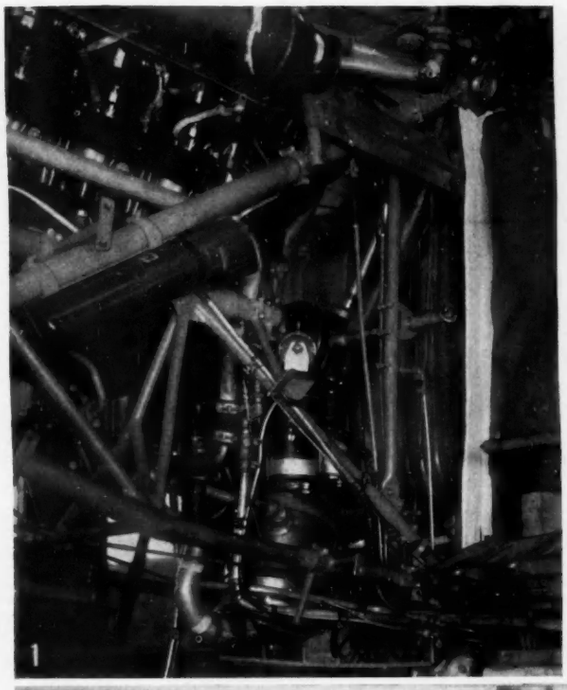
Engine-Mounting Is the First Problem

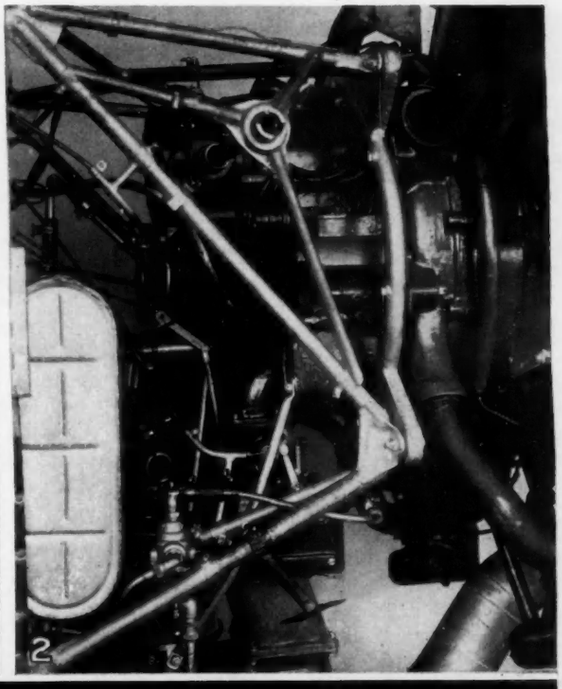
The introduction of the cabin airplane has increased the difficulties of proper engine-mounting and very careful consideration should be given to this problem from a standpoint of comfort to the pilot and passengers. Several methods are used in modern aircraft, but nearly all of them use the same sort of steel tubular structure for attaching the engine to the airplane body. One of the simplest forms of mounting is to make tubular rings to which are welded lugs for the engine bolts. The

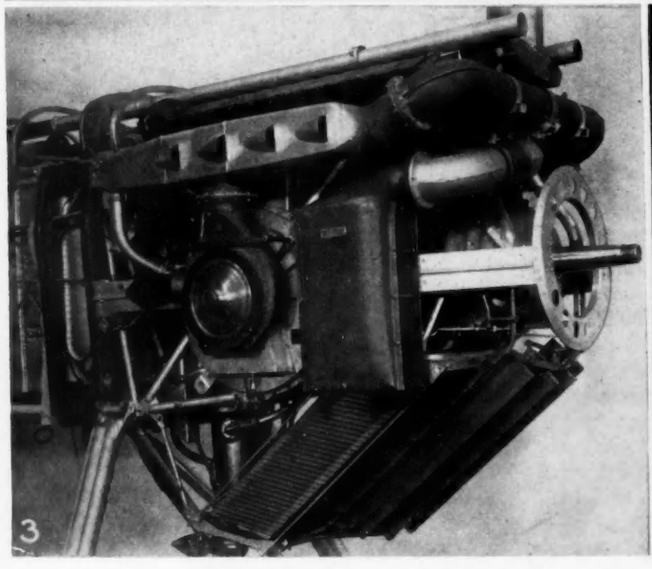
[1] M.S.A.E.—Chief engineer, motor division, Curtiss Aeroplane & Motor Co., Inc., Buffalo, N. Y.

structural members from this ring to the airplane body are welded to the ring and are bolted to four points of the airplane body at the longerons. As a general rule this welded structure is made inaccurately, resulting in high stresses in the engine crankcase on account of the misalignment of the engine lag-bolts. The reason for this inaccuracy is probably due to the limited production of airplanes and the lack of the proper jigs and fixtures when machining the bolt-holes, if the structure is welded together.

In some instances, to overcome this trouble, it has been necessary to provide a forging or a cast-aluminum ring which can be machined accurately and which will absorb the loads from the tubular structure to prevent them from being transmitted to the engine crankcase. Any failure of this ring caused by these initial strains will not hurt the engine and, if failure should take place, it will not be in an expensive crankcase. This method of construction operates satisfactorily, but an unnecessary amount of weight must be carried. There







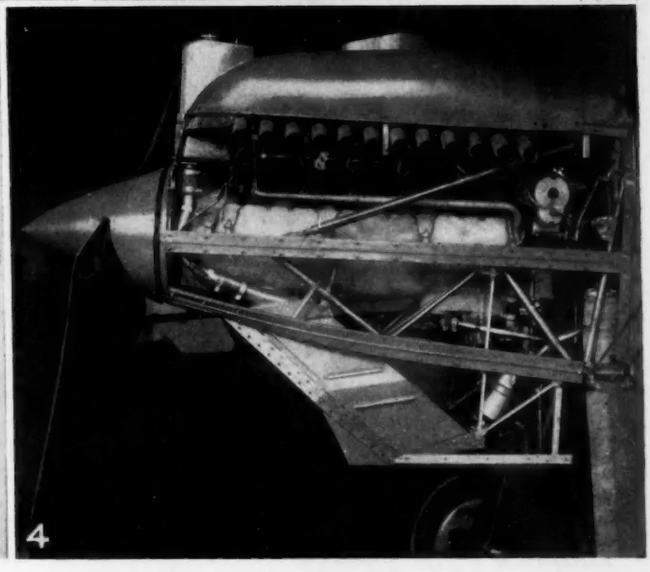


FIG. 1—THE ILLUSTRATION ENABLES ONE TO REALIZE THAT THE PROBLEM OF INSTALLATION IS NOT SOLVED EASILY

FIG. 2—FIND THE NUMBER OF MISTAKES IN THIS INSTALLATION

FIG. 3—INACCESSIBILITY IS A GREAT HANDICAP

The Problem Here Seems To Be To Find the Engine. In This Case, Inaccessibility Is Caused Mainly by the Built-On Supercharger

FIG. 4—AIRCRAFT-ENGINE INSTALLATION MADE IN 1925

The Author Requests Readers to Consider Whether This Is a Better or a Worse Installation Than Those Which Are Being Made at Present

appears to be a tendency to use structures in engine mounts which are full of eccentric loads. Any structure built up in this manner lacks rigidity and often has periods which are in synchronism with the engine, all of which might be avoided by proper design.

The attachment of this tubular structure to the airplane body is often accompanied by the use of four ordinary heat-treated alloy-steel bolts. Sometimes the bolt-holes are reamed. I have never seen any bolts which have been ground. The use of an attachment of this kind, particularly when the bearing area of the tubular structure is so small, results in looseness after the airplane has been in service. To overcome this difficulty adequate bearing area should be provided and nutted taper-pins used.

In the design of the tubular engine-mount structure, more attention should be paid to the rigidity required, rather than to a pure analysis from a tensile-strength standpoint. Many stresses will be set up in a structure if there is insufficient rigidity, and it is impossible to figure the magnitude of these stresses. It is therefore advisable to use tubes of large diameter and fairly heavy wall, and the design should be complete within itself without going through any pin joints to obtain this complete structure. In the design of this structure accessibility should be given prime consideration. Accessories on the engine should be easily removable as well as accessible. (See Figs. 3 and 4.)

Carburetion and Fuel System

The connection of the carburetion system to the airplane is the first important item. The gravity system should be used whenever possible, as it is the simplest form and is the most reliable. As simple as a gravity gasoline-system appears to be at first glance, there are many errors that can be and have been made. Information should be obtained on the minimum head or pressure required at the carbureter to feed the necessary quantity of fuel to the engine. I have seen an installation which would operate without trouble with the airplane tail on the ground; but, as soon as the tail was raised during the take-off, the engine died on account of lack of fuel and this is a dangerous characteristic. Large fuel-lines must be used to eliminate friction-head losses and to provide sufficient static head.

Gasoline lines are often effectively hidden from view, so well, in fact, that periodic inspection is hopeless and replacement is impossible without ripping the airplane apart. Such installation should be avoided because quick replacement is of prime importance, particularly on airplanes used on scheduled routes. The attachment of lines to the airplane structure should be made with adequate steel-clips having soft, durable insulation between the clip and the member to which the attachment is made to prevent chafing. Connection of gasoline to the engine should be made with gasoline-resisting rubber-hose properly protected with metal liners. Sharp bends and kinks should be avoided.

Experience has shown that the fuel strainers provided in carbureters are inadequate to stop water from getting into the carbureter jets which, of course, causes trouble instantly. Some carbureters have no strainers. Therefore, a strainer of ample capacity should be installed near the carbureter and the drain from this strainer located so that it can be opened easily, without the use of too many tools and, preferably, without tools.

The use of a gasoline pump is imperative on many airplanes. This increases the cost and adds complications. The usual geared gasoline-pump has no ability to operate on a negative head, and this fact is disregarded very often to such an extent that the engine will not idle for extensive periods unless the pilot operates the auxiliary hand-pump occasionally to keep gasoline in the carbureter float-chamber.

To prevent vapor lock, it is advisable to return the overflow gasoline from the pressure-relief valve to the source of supply. To avoid this extra line, the overflow is often returned to the suction side of the gasoline supply and the result is often disastrous. However, when using the latter system, trouble can be avoided by taking off the relief line at a point below the higher point in the discharge line so that any air or vapor bubbles will pass off through this discharge line into the fuel strainer and the carbureter float-chamber. I favor the use of a fuel pump, a bypass valve for the hand pump, and a relief valve, built into one unit, although this unit is not in general use at present. The silver-soldered type of pipe connections appears to give the best satisfaction.

Engine Lubrication and Cooling

The operation of an aircraft engine can be improved and its life prolonged by proper installation of the oiling system. In combining the airplane and the engine it appears often that no thought is given to the oil-tank and oil-cooler location until the airplane is almost built; then, the tank is tucked away in whatever space is left. The odd shapes of tank cause fatigue failures on account of their many acute angles and multiplicity of joints. I have even seen an oil tank located under the pilot's seat. The tanks are often shielded effectively from fresh cool-air circulation. Engine-compartment temperatures at normal air-temperatures often reach 140 deg. fahr., and oil tanks surrounded with air at this temperature are well heated in cold as well as in warm weather, which is a dangerous condition. (See Fig. 5.)

Unfortunately, almost all oil thermometers on aircraft engines are located to measure the temperature of the oil that enters the engine, but many engines today are operating at oil-outlet temperatures up to 250 deg. fahr., although the pilot, when reading the thermometer, may think the maximum oil-temperature in the engine is below 200 deg. fahr. which is as it should be if the proper cooling were provided. An oil-inlet temperature of 170 deg. fahr. is preferable. New installations should always have thermometers installed to check oil-inlet and oil-outlet temperatures. This is very important on the higher-powered engines which have such great power per unit of oil-cooling surface on the engine.

Adequate unit air-cooled oil-coolers of light weight and small frontal area have been developed and are available. The location of these coolers and the leading of air to them are of the utmost importance from the standpoint of efficiency.

Where space is available, sufficient oil cooling can be obtained in the oil tank alone, and this is a very desirable method because the oil-temperature control is facilitated. The method, however, often adds more weight than when using the unit cooler. Water-cooled oil-temperature regulators have been used very successfully, but the air-cooled oil-cooler is lighter and may

FIG. 5—ENGINE COMPARTMENT AND OTHER FEATURES CRITICIZED

An Air Temperature of 140 Deg. Fahr. Was Experienced in the Engine Compartment Shown Until Subsequent Changes Were Made. The Exhaust System Is of an Undersirable Type and the Oil-Cooler Location Is Poor

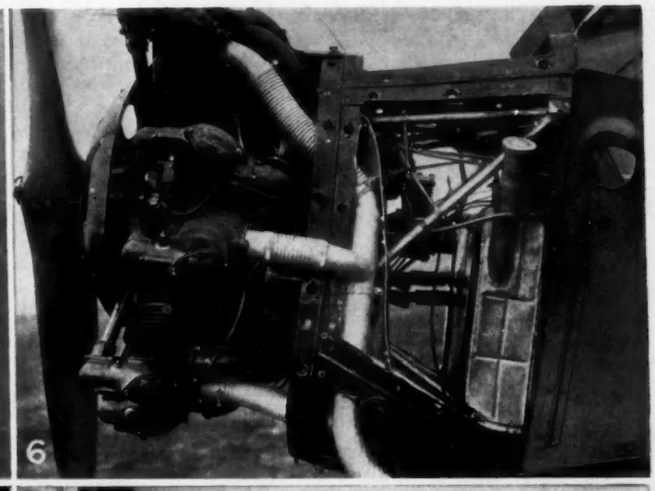


FIG. 6—RADIAL-ENGINE MANIFOLDING

The Difficult Problem of Satisfactory Exhaust-Manifold Installation on a Radial Engine Can Be Solved Fairly Well as Shown

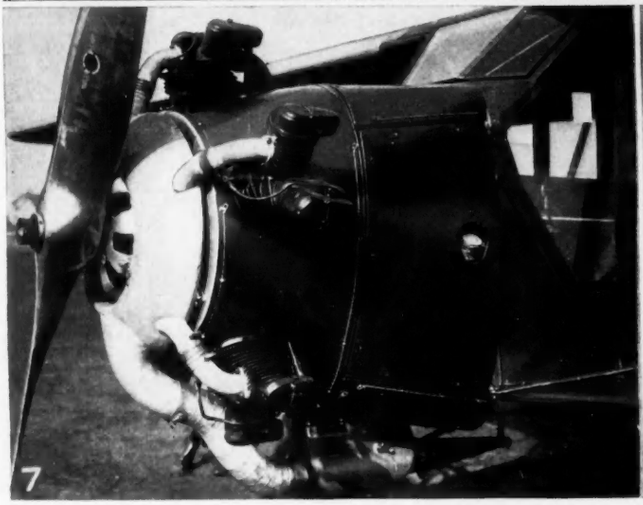


FIG. 7—TYPICAL FRONT EXHAUST-SYSTEM

The Front Exhaust-System Shown Is Neat, But It Is Undersirable from an Engine-Cooling Viewpoint. The Air Heater Is in a Poor Position

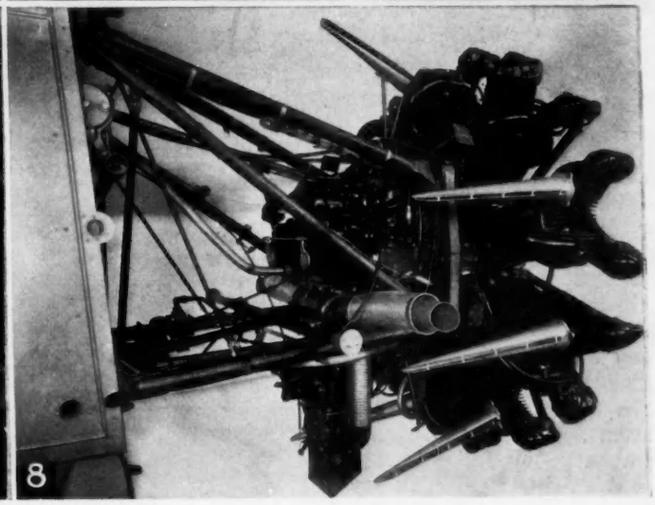


FIG. 8—INSTALLATION OF AN UNDESIRABLE TYPE OF CARBURETER AIR-HEATER

supersede them. The former type has the very desirable feature of heating the oil quickly in cold weather.

Oil lines must be large and unrestricted owing to the high viscosity of oil in the winter. Bypass valves are sometimes required around the unit oil-coolers to prevent excessive pressures from building-up. Adequate beading on oil lines will prevent necessary hose connections from blowing off on account of pressure caused by cold oil when the engine is started. Double beads and two hose-clamps on each member will hold a pressure of more than 500 lb. per sq. in.

Exhaust-manifolding equipment always should be provided with the engine, and the airplane designer should keep in mind that the engine mount must clear these manifolds. The front exhaust-collector apparently was developed on account of the ease with which interference with the structure in the rear of the engine can be avoided; but its use entails some sacrifice in engine design. (See Figs. 6 and 7.) It appears that special material which will not be attacked by ethyl-fluid mixture will be required in the manifolds.

Carbureter Heating Discussed

Too little attention has been paid by engine designers to proper carbureter heating. (See Fig. 8.) The result is the development of various types of air-heating devices which have been given descriptive but sometimes uncomplimentary shop names. The result of inadequate heating of the carbureter and induction system has resulted in an attempt by operators to obtain this heating by cowling the cylinders effectively. How they can expect to get good results in this way is beyond one's comprehension; but it is done frequently, regardless of the detriment to the engine on account of the higher and sometimes dangerous cylinder-temperatures.

It is desirable to jacket the throttle-barrel section of the carbureter, and it is imperative to provide a hot-spot on which the heat can be controlled. The atomized fuel leaving the carbureter should impinge against

the heated surface, and this should have a temperature of about 350 deg. fahr. Too much heat means a loss of power, and too little heat results in poor carburetion, increased wear on the cylinders and pistons and particularly on the piston-rings. A jacketed carbureter must be provided if sufficient warm air from the engine is not available to prevent ice formation around the cap jets and the butterfly valve. This ice formation is very dangerous, as it ultimately can stop the engine, and it interferes seriously with proper carburetion.

A properly designed carbureter-heating system requires only part of the exhaust from one cylinder and the amount of heat in the engine compartment is therefore reduced to the minimum. There is no excuse for heating systems which require the total exhaust-heat from several cylinders. The resulting temperatures inside the engine compartment are dangerous and, if the unit is located outside the cowling, it is unsightly and adds considerable resistance and weight.

Wiring and Controls Analyzed

The electric-wiring problem is becoming more important and should receive more attention; the wiring should be accessible and easily removable. Where connections are made to storage batteries they should be designed to withstand fatigue, because failure during flight might cause fire. The use of conduits to group wires and simplify installation should be encouraged. The same care in clipping wire or conduits to the airplane should be exercised as with other lines, to prevent chafing of either the structure or the wires.

There is a decided absence of engineering in designing the controls from the engine to the pilot's cockpit. The airplane designer and the production engineer seem to have determined to save every possible cent on this item. There is a gross lack of bearing area and an abundance of flexibility and lost motion, all of which helps to worry the pilot. How the mixture control can be set properly with the average controls is a mystery. Poorly installed wire-controls are often used, and the use of such controls should not be permitted. Throttle controls which are installed so that they will not stay in any position without holding them, or which work too hard, should not be used.

FIG. 9—INSTALLATION OF A HEXAGON TYPE OF ENGINE

The Possibilities of a Neat Installation of the Hexagon Type of Engine Are Indicated. The Type of Cowl Fasteners and the Large Number of Fasteners Used Should Be Noted

Indications point now to the possibility of eliminating spark control, which will tend toward simplification. Controls are one of the left-over design-problems not usually considered in the basic design. They should be engineered, and not merely built.

Too little respect is paid to slipstream effects, and aircraft-engine cowling receives the friendly support of the welding torch too frequently. The production engineer likes to use pure sheet aluminum for cowls, and uses it often, although it has neither proper strength nor stiffness. Heat-treated duralumin is often used, or rather, abused. The result is that, on account of insufficient annealing and subsequent heat-treating, it is worse than the pure aluminum. Suitable alloys are available for this purpose and they should be used. The cowling should be designed for removal from the engine easily, and for replacement as easily and as quickly as possible. After a number of removals, the cowling on many engines looks as though can openers, crowbars and hammers had been used on it. Therefore, a very strong appeal is made for improvement in cowling. (See Fig. 9.)

From an aerodynamic viewpoint, many beautiful cowls have been made, but they are put together with countless machine screws and nuts. To avoid a nervous breakdown, do not attempt to interchange this type of cowling on another airplane of the same construction. The average cowling is the greatest oil-cooling preventive and a fraction of aerodynamic efficiency might be lost if air were permitted to circulate in the engine compartment. The development of an inexpensive, rigid, strong cowl-fastener would be very welcome at this time.

The same care should be taken in installing radiators for water or liquid cooling as is taken with any of the other piping systems. Particular attention should be exercised in mounting the radiator to provide against vibration and shock. The radiator development for the last 10 years has been negligible. As a result, the liquid-cooled engine is penalized with very heavy large radiators. Research work on radiators and circulating systems should develop improvements if attacked in earnest. The engine designer should shoulder this responsibility, as it is a power-plant problem and very important.

Many of the statements made in this paper may be somewhat harsh, as the solutions of the difficulties are not obtained easily. But progress along installation lines has been very slow during the last 15 years. In general, installations should be simple so that it is possible to work on any part of the engine without removing other parts. The least number of connections should be broken and parts removed when it is necessary to remove the engine from the airplane. I realize that I have omitted many details in this paper, but if the haywire, friction-tape-and-shellac type of installation can be eliminated, it will be a great contribution toward the safety and advancement of the aircraft industry.

THE DISCUSSION

F. W. HECKERT[2]:—Having been engaged for over eight years in aircraft-powerplant work with the Army Air Corps, I am conscious of many of the shortcomings of aircraft powerplant design and installation, and I should like to make a general statement concerning them.

The Air Corps has had a continuous battle with the manufacturers to obtain satisfactory installations so as to eliminate the troubles that cause dangerous conditions, and to compel a manufacturer who has a contract with the Government to install the features which it feels, on account of long experience, are necessary.

There should be more direct cooperation between the Department of Commerce and the Army and Navy Departments because the service to which Army and Navy aircraft are subjected is more than ordinarily severe. The Army and Navy possess data that would be of great help to commercial-aircraft builders who, in some instances, are very careless in providing satisfactory engine controls, fuel and lubricating systems, plumbing and the like. In one instance an airplane was exhibited at a recent Aircraft Show in which the fuel in a gravity-feed system actually had to run uphill in normal flight attitudes. After the fuel dropped below a certain level, no flow to the carbureter was possible.

F. W. HECKERT

The Air Corps also has had to fight the use of machine screws to fasten the cowling. We are still looking for a perfectly satisfactory cowl and attachments. Conditions are similar for radiators and other parts. By persistently working along certain lines and insisting that certain standards be maintained with respect to engine controls, fuel and lubricating and cooling-system units, the Army Air Corps has eliminated many installation defects and now is doing more intensive work along the line of washing out so-called hodge-podge plumber's exhibitions that one may see in many installations. We had to struggle along for a considerable time to demonstrate the value of our proposition. Once having demonstrated the value of certain proved features, the next step is the tying up of proved powerplant-units in an attempt to clean the "plumbing"; because it is a recognized fact that every fuel-line connection, for instance, is a fire hazard. In other words, in the case of fuel systems, the combining of certain proved standard units has eliminated fuel lines and connections.

CHAIRMAN GEORGE W. LEWIS[3]:—What is the most satisfactory oil-cooling system found on air-cooled engines at Wright Field?

MR. HECKERT:—We are practically standardized on the cartridge core-tube type of cooling unit. The tubes are about 9 in. long and are made up in a circular unit to provide desirable surfaces for the shell. All surfaces must be curved so as to withstand the pressures.

I concur with Mr. Nutt that, if the oil thermometer were placed on the oil-outlet line, not many pilots would fly the airplane because the oil temperature would seem to be too high. This would scare the pilot, so that he would be likely to come down on the first landing-field available. If we continue to build engines of tremendous output, we can expect to reach dangerous limits in the oil temperatures. It is a battle to get an oil-cooling system that will cool adequately. A majority of the airplanes use air as a temperature-control medium. Water-cooling is good, as Mr. Nutt pointed out, from the standpoint of getting the oil warm in cold weather; but the tendency in the Army Air Corps has been to use the air-cooled type.

CHAIRMAN LEWIS:—What has been the most satisfactory method found in providing a hot-spot on the carbureter?

MR. HECKERT:—We have not determined which is more satisfactory, whether to heat the air going into the carbureter, or provide a hot-spot. In some cases the hot-spot is the more desirable. However, one manufacturer is a proponent of the use of directing heated air into the carbureter intake. This guards against the tendency to have ice form around the throttle. The hot-spot tends to give better distribution; but this becomes a case of deciding which one wants, whether to stay away from the dangers of ice formation, or to use a hot-spot to secure smoother running and better distribution.

CHAIRMAN LEWIS:—Do you consider the providing of a hot-spot for preheating the air going to the carbureter as necessarily creating a fire hazard?

MR. HECKERT:—Yes, because we have a serious situation in that regard in our radial engines of today. The carbureter is mounted low and the oil and fuel lines and fuel pump are jammed so close together at the rear of the engine that the failure of a line or a gasoline leak could cause a fire by coming into contact with the hot-spot. We must exercise great care to direct the lines in such a way that the minimum danger exists, and to see that the proper connections are made.

As to fuel-line connections, the Army Air Corps has one very hard and fixed standard in regard to fuel lines that are subjected to vibration. When the lines extend from the structure to the engine, we insist that hose connections be used, on the assumption that the structure has certain periods of vibration and that the engine has other periods. The so-called shock-absorber for the fuel line is the standard hose-connection made at each end of the line, the remainder of the fuel lines having solid connections. This works out very well. In looking over the crash reports, particularly in the Army, we seldom find that a forced landing is made due to fuel-line or oil-line failures, which is largely because we insist on having certain standards adhered to.

LIEUT. C. A. ROSS[4]:—On the subject of oil coolers, the Fokker C7 tri-motored plane which I piloted to California was equipped with coolers such as Mr. Heckert has mentioned. They were installed in January, 1930,

(*Concluded on p.* 343)

[3] M.S.A.E.—Associate mechanical engineer, powerplant branch, U. S. Army Air Corps, Materiel Division, Wright Field, Dayton, Ohio.

[3] S.M.S.A.E.—Director of aeronautical research, National Advisory Committee for Aeronautics, City of Washington.

[4] Engineer, powerplant branch, U. S. Army Air Corps, Materiel Division, Wright Field, Dayton, Ohio.

Automobile-Engine Acceleration[1]

By Clarence S. Bruce[2]

Semi-Annual Meeting Paper

Illustrated with Photographs and Charts

MARKING the completion of the investigation of engine acceleration in connection with a study of the economic volatility of motor fuels that has been under way since 1920, the paper is in the nature of a final progress-report and presents a summary of the results obtained. The earlier work done is reviewed briefly, following which the phase of the work that the paper covers, comparisons of fuel performance with downdraft and updraft induction-systems and with three separate carbureters connected by short pipes to the three intake ports of the engine, is described. Although the latter arrangement roughly represents cold carburetion, complete parallelism with the other series of tests is not possible since the three carbureters were not equipped with accelerating-charge pumps.

The effect of the accelerating-charge pump was brought out in the discussion, a car so equipped traveling 160 ft. in 6 sec., while other cars of the same make but not fitted with the pump required 0.2 sec. more. Another point raised was the influence on acceleration exerted by the character of the interior surface of the manifolds. In reply, the author said that this factor had a great effect.

THE measurement of engine acceleration was undertaken by the Bureau of Standards in connection with an investigation of the economic volatility of motor fuels, initiated about May 1, 1920, by the Society's Committee on the Utilization of Present Fuels in Present Engines. Later the work was continued under the direction of the Steering Committee of the Cooperative Fuel Research. That part of the investigation relating to engine acceleration has now been concluded. This paper constitutes a final progress-report and presents a summary of the results.

The method first used for measuring acceleration, described to the Society in papers[3] by W. S. James, Dr. H. C. Dickinson and S. W. Sparrow, consisted essentially of letting the engine idle at low speed with light load, then suddenly opening the throttle fully and noting the successive readings of a chronometric tachometer until a speed of 1800 r.p.m. was reached. Elapsed time and engine revolutions were recorded on a chronograph. Results were expressed as speed-time curves, and it was concluded that "within the limits of this work the greater the amount of heat supplied to the charge and the higher its temperature at the intake port, the more rapidly the engine will accelerate."

With the organization of the Cooperative Fuel Research, in the summer of 1922, came further work on fuel volatility. The work was done on the road, using two makes of car, and was reported to this Society in papers by R. E. Carlson[4] and Roger Birdsell[5]. A graphic record of car-speed changes during runs was obtained by connecting a pen movement to a Van Sicklen chronometric tachometer. The conclusion reached was that the effect of differences in volatility of the fuels on acceleration was not measurable by road test. Laboratory tests, however, did show decided differences in acceleration results between fuels which differed in volatility but had nearly the same initial-distillation point. As an appendix to Mr. Birdsell's paper, a mathematical discussion was given by W. S. James[6] of the design of the inertia disc used in laboratory tests to simulate the inertia of the car.

On Dec. 4, 1925, the Steering Committee of the Cooperative Fuel Research Committee recommended that "The study of engine starting, which had thus far dealt with the obtaining of the initial start, ultimately should cover the behavior of the engine during the warming-up period, particularly as regards acceleration." A preliminary study of engine acceleration was made, using a chronometric tachometer, and reported by J. O. Eisinger[7]. This work showed decided differences in initial lag under different conditions and, to a lesser degree, differences in acceleration can be inferred from the speed-time curves. In the course of this work it was desired to determine the acceleration obtained with each of three fuels having widely different American Society for Testing Materials 50-per cent points. The results obtained and reported by R. Best and J. O. Eisinger[8] were not sufficiently accurate to lead to definite conclusions.

Because of the insufficient accuracy of the chronometric-tachometer method of measuring acceleration, a study of other possible methods was made. In June, 1928, D. B. Brooks[9] reported:

> An adaptation of the displacement-time method, which has been adopted for use in this investigation, consists in driving a paper tape at a speed proportional to the engine speed and discharging a spark through the tape at equal time-intervals. A displacement-time record is thus obtained, the second derivative of which gives the acceleration. One reason for selecting this particular method is that the absolute measurements involved can be made with sufficient precision to permit of double differentiation and still yield results of the desired accuracy. Further increase in accuracy can be obtained by increasing the ratio of tape speed to engine speed.

The apparatus, constructed on this basis and known

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[1] Publication approved by the Director of the Bureau of Standards of the Department of Commerce.

[2] S.M.S.A.E.—Assistant engineer, Bureau of Standards, City of Washington.

[3] See THE JOURNAL, August, 1920, p. 131, and January, 1921, p. 3.

[4] See THE JOURNAL, February, 1923, p. 139.

[5] See THE JOURNAL, March, 1924, p. 267.

[6] See THE JOURNAL, March, 1924, p. 271.

[7] See THE JOURNAL, August, 1927, p. 184.

[8] See *Bulletin of the American Petroleum Institute*, Jan. 31, 1928, p. 74.

[9] See S.A.E. JOURNAL, September, 1928, p. 235.

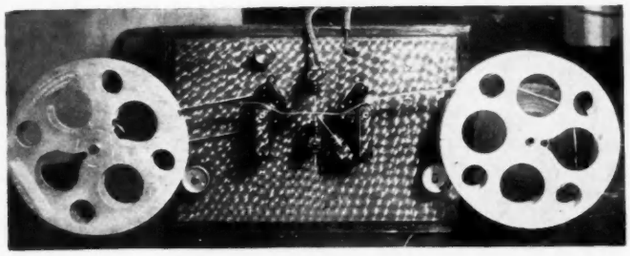


FIG. 1—FRONT VIEW OF PORTABLE MODEL OF SPARK ACCELEROMETER

as the spark accelerometer, was used in a study of the effect of operating factors and of fuel volatility on acceleration performance. In the course of this study a relation was found between the distillation curves of fuels and their effectiveness for producing acceleration. The results[10] indicated that if this relation were equally applicable to engines other than the one used in making the tests it would be possible at least to estimate the relative acceleration performance with different fuels from their distillation data.

The Steering Committee recommended that these tests be extended to include engines differing in design. Fig. 1 shows a portable model of the spark accelerometer, described[11] and exhibited at the 1929 Summer Meeting, which was used in making these tests at the laboratories of four automobile companies. Further tests were then made with this apparatus at the Bureau of Standards. The results of these field tests reported[12] at the 1930 Annual Meeting showed a fair agreement with the relation previously found.

Final Fuel-Volatility Tests

At this time a fuel became available having a volatility such that, used in comparison with a fuel prepared especially for acceleration work, it offered an opportunity for a very delicate test of the relation previously found. Distillation curves of these fuels are shown in Fig. 2.

As stated in previous reports, the measure of relative fuel-volatility found to give curves similar to those derived from acceleration tests is obtained as follows: One fuel is selected as the reference. Its volatility is taken as unity at all temperatures. At 5 per cent evaporated, the A.S.T.M. temperature, in degrees absolute, for the reference fuel is divided by that for one of the other fuels, in this case Fuel *D*. The value so obtained is called the relative volatility of Fuel *D* with respect to the reference fuel, *A*-1. This procedure is then repeated at successively higher percentages evaporated. By plotting the values so obtained at each percentage evaporated against the A.S.T.M. temperature of the reference fuel at the same per cent evaporated, the curve of relative volatility shown in Fig. 3 is obtained. It is emphasized that this curve was derived solely from the A.S.T.M. distillation-data for the two fuels.

The curve of relative effectiveness of these fuels for producing acceleration, shown in Fig. 4, is, on the contrary, derived solely from engine-acceleration test-data for the fuels and does not involve A.S.T.M. data in any way. The effectiveness of a fuel for producing acceleration is defined as the air-fuel ratio supplied by the carbureter divided by the air-fuel ratio entering the cylinders at the same instant. As described more fully in a previous report[13], the effective air-fuel ratio is found by comparing the curve of observed acceleration, at a speed 50 r.p.m. above the initial speed, with a contour chart derived from brake-torque versus mixture-ratio tests at various constant speeds. Since acceleration at any instant is proportional to available brake-torque, the effective air-fuel ratio found is that mixture which, if vaporized and distributed as under constant-speed operating-conditions, would give brake torque sufficient to produce the observed acceleration. To minimize the effect of differences in supplied air-fuel ratio, speed and so forth, results are expressed as effectiveness of the fuel relative to one fuel chosen as a reference in the same manner as the relative volatilities.

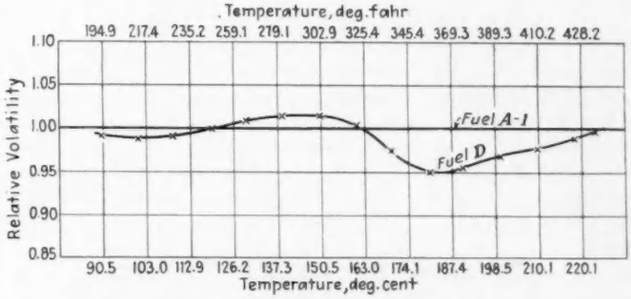


FIG. 3—RELATIVE VOLATILITY OF FUELS *A*-1 AND *D*

While the relative effectiveness of the fuels is given, for the sake of clearness of discussion, in terms of air-fuel ratios, it should be understood that these ratios are not capable of being measured directly and may not even be equal to those delivered. The ratios are deduced indirectly from the observed accelerations and may be considered effective ratios, which, on the hypotheses used, would produce the accelerations observed.

From Figs. 2 and 3, it can be seen that the difference in volatility between the fuels is very small. Furthermore, the distillation curves intersect four times. If the relation previously found holds good, it would be necessary that the curves of relative effectiveness for

[10] See S.A.E. JOURNAL, June, 1929, p. 609.
[11] See S.A.E. JOURNAL, August, 1929, p. 174.
[12] See S.A.E. JOURNAL, April, 1930, p. 471.
[13] See S.A.E. JOURNAL, June, 1929, p. 609.

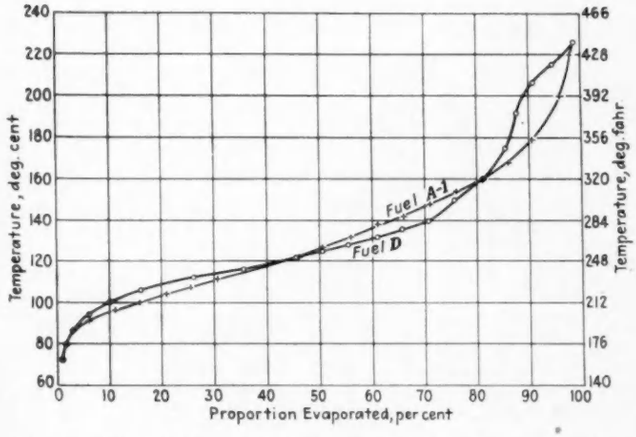


FIG. 2—DISTILLATION CURVES OF FUELS *A*-1 AND *D* USED TO CHECK VOLATILITY RELATION

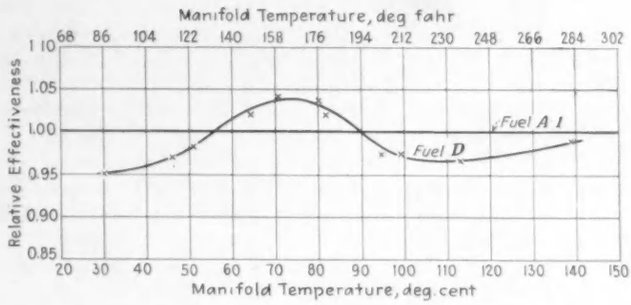


FIG. 4—RELATIVE EFFECTIVENESS FOR ACCELERATION OF FUELS *A*-1 AND *D*

acceleration intersect four times, provided that the manifold temperature were varied over a sufficient range. In these tests, high manifold-temperatures were made possible by use of ethylene glycol in the manifold jacket.

Due to the small difference in volatility between the fuels, more than usual care was taken in maintaining constant test-conditions in order that accidental errors might not obscure any real differences in acceleration performance. The results, shown in Fig. 4, are believed to represent the most precise set of acceleration tests yet made.

From the intersections of the *D* and *A*-1 curves in the two charts, the relation between manifold and corresponding A.S.T.M. temperatures can be found. For each intersection, the A.S.T.M. absolute temperature is found to be 1.20 times the manifold absolute temperature. This value of the temperature factor is in good agreement with values obtained on previous tests, these latter ranging from 1.18 to 1.22, but averaging 1.20. Use of this factor to estimate acceleration performance from A.S.T.M. distillation-data is explained in a previous report[14].

Coincident with the introduction of fuel pumps in automotive work has come an increased interest in downdraft carbureters and manifolds. Since acceleration performance is primarily a function of the volatility of the fuel and the behavior of the induction system, it was felt that this research should include a direct comparison of downdraft with updraft induction. In Fig. 5 the acceleration-test engine is shown with the manifold inverted to take a downdraft carbureter. Fig. 6 shows this engine with the same manifold in its normal or updraft position and equipped with an updraft carbureter. The same size of venturi was used in each carbureter; however, that in the downdraft carbureter was obstructed to a greater extent by the jet.

Acceleration tests were run on both types of induction system with carbureters set for each of several air-fuel ratios. Under each of these conditions, a series of tests was made, varying the accelerating charge. Parallel with these tests, runs were made using three 1-in. carbureters coupled to the block by pipes about 2 in. long, as shown in Fig. 7. These three carbureters were adjusted separately to have equal characteristics. The throttles were interconnected and were adjusted for equal power when operating at normal load at 300 r.p.m. Acceleration tests and power and mixture ratio versus speed measurements were made at four carbureter settings.

While this entirely dispenses with the manifolds, thus affording an interesting comparison with the updraft and downdraft test-series, it yet represents, in an elementary way, cold carburetion. Complete parallelism with the other two series of tests was not possible, as these carbureters did not have accelerating-charge pumps.

Typical results on the updraft and downdraft induction-systems are shown respectively in Figs. 8 and 9. Results of the multiple-carbureter tests are shown in Fig. 10. In Figs. 8 and 9, the effect of increasing the accelerating charge is very clearly shown, the acceleration below about 700 r.p.m. being improved with each increase in charge. However, other tests, not presented here, show that too large a charge reduces the acceleration in this range.

In connection with these curves attention is called to the fact that only from acceleration curves can the correct proportioning of the quantity and rate of injection of accelerating charges be determined with precision. Measurement of total time required for a given increase of speed will not indicate whether too much or too little charge has been used; speed-time curves are somewhat more instructive but do not give quantitative informa-

[14] See S.A.E. JOURNAL, April, 1930, p. 474.

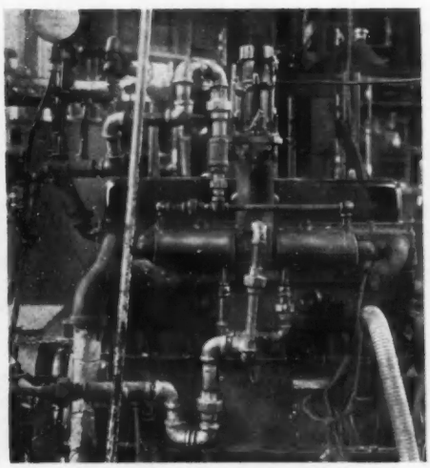


Fig. 5—Downdraft Induction-System

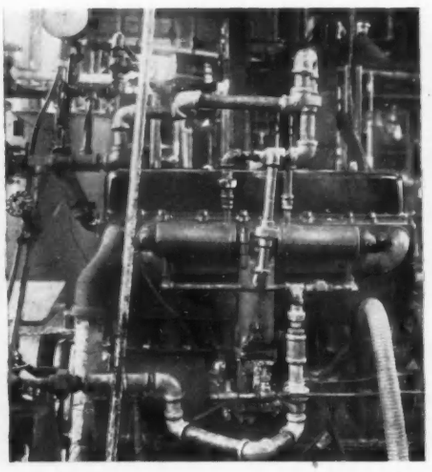


Fig. 6—Updraft Induction-System

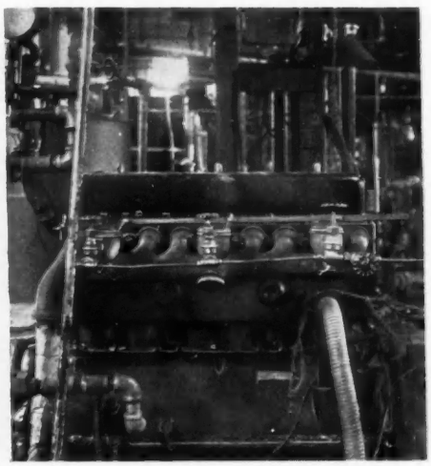


Fig. 7—Three Carbureters Attached

THREE ARRANGEMENTS OF THE TEST ENGINE

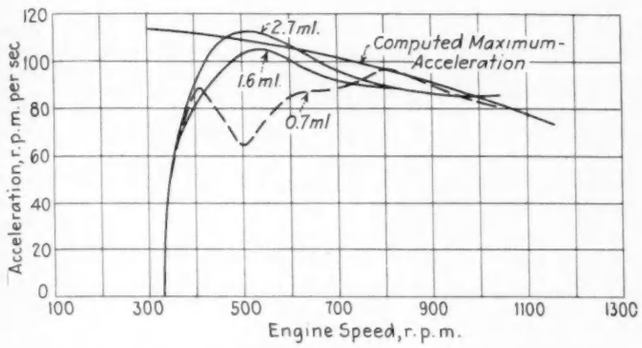


FIG. 8—TYPICAL ACCELERATION-CURVES OBTAINED WITH UPDRAFT INDUCTION-SYSTEM

tion. From the curves here presented, by noting the amount that the observed acceleration falls short of the computed maximum shortly after the start of the acceleration, an estimate of the correct charge may be made readily.

However, to compare the acceleration performance of different types of induction system, it is necessary to eliminate effects due to carbureter characteristics, since it is not possible to use the same carbureter in the two cases and is not feasible to make the characteristics of the updraft and downdraft carbureters identical. A suitable method of analysis, fully described in a previous report[15], consists essentially in conversion of the observed acceleration into units of torque and, from the latter with the aid of mixture-ratio-torque curves obtained from constant-speed runs, estimation of the "effective" air-fuel ratio required to produce the observed acceleration. From a comparison of the values of effective air-fuel ratio so obtained with the known carbureter metering-characteristics, a time plot is made of the ratio of fuel leaving the manifold to fuel supplied by the carbureter. This type of chart, one of which is shown in Fig. 11, is practically a "manifold-efficiency" chart.

Since the settings on up and downdraft carbureters could not be made to give identical mixture-ratios, it was necessary to derive from the manifold-efficiency charts a set of values which, when plotted against mixture ratios, would be a measure of manifold performance. Plotting the time values at which the curves for each type of induction system intersect the 0.9 ratio line against supplied mixture-ratio gives the curves shown

[15] See S.A.E. JOURNAL, September, 1928, p. 240.

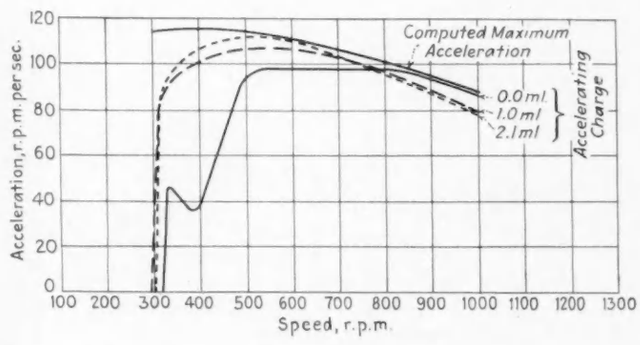


FIG. 9—TYPICAL ACCELERATION-CURVES OBTAINED WITH DOWNDRAFT INDUCTION-SYSTEM

in Fig. 12. It is seen that the largest time difference between the two curves is about 0.5 sec. and that at the same mixture-ratio the two induction-systems show but little difference in performance. From this analysis it seems that the effect of gravity on the induction of fuel is negligible under acceleration conditions, in comparison with the effects of other factors, such as the adhesive and viscous forces retarding flow of fuel along the manifold walls. Referring again to Fig. 10, several inferences may be drawn from these curves obtained with a carbureter attached to each port in the block.

The test in which the mean air-fuel ratio was 11.9 shows reasonably rapid increase of acceleration to the computed maximum; at 300 r.p.m. the supplied air-fuel ratio was about 13. With so lean a mixture, no acceleration would be obtained with the ordinary manifold-system. The fact that computed maximum-acceleration is not at once realized, however, indicates that time and fuel are required to wet even the short induction system here used. In the more exact analysis, Fig. 11, this fact is clearly shown. The leanest test-run requires somewhat more than twice as long to reach the standard performance value of 0.9 than does the rich-

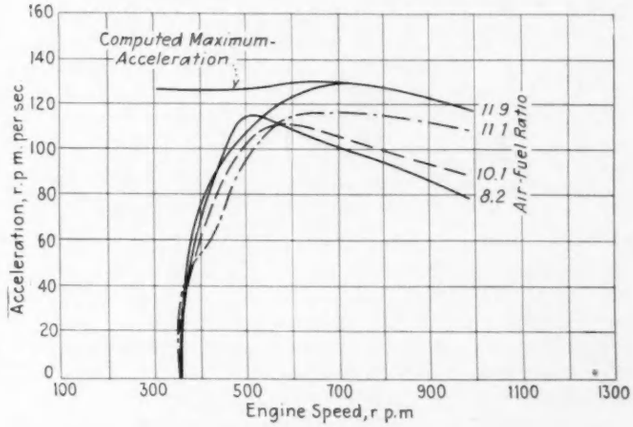


FIG. 10—ACCELERATION CURVES AND MIXTURE RATIOS USED IN THREE CARBURETER TESTS

est, indicating that roughly the same quantity of fuel is required in both cases.

Lastly, just as maximum acceleration is more rapidly attained with this simplified induction-system, so is the effect of too rich a mixture shown at an earlier point on the acceleration curve. Thus the 8.2 to 10.1 air-fuel ratio runs, Fig. 10, show the effect of over-richness after about 550 r.p.m. It has been found necessary to maintain the initial speeds very nearly equal on successive runs to obtain acceleration curves suitable for this analysis.

Résumé

In the course of these investigations of engine acceleration the following results have been obtained:

(1) Road acceleration-tests have been demonstrated to yield information neither sufficiently precise nor sufficiently detailed to permit determining definitely the causes of readily detectable differences in acceleration performance.

(2) A portable spark-accelerometer has been developed, with which engine acceleration can be

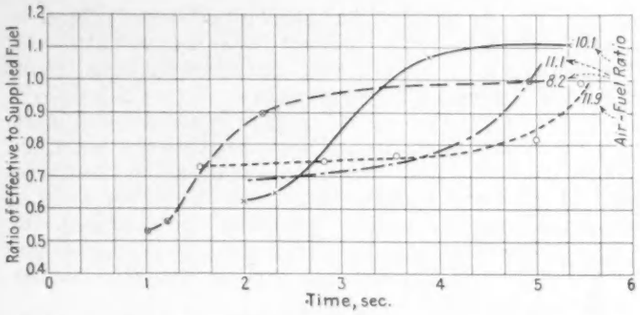


FIG. 11—INDUCTION-SYSTEM PERFORMANCE USING THREE CARBURETERS

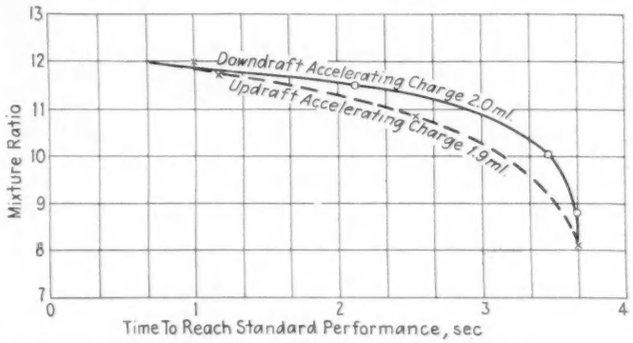

Mixture Ratio
Time To Reach Standard Performance, sec
Downdraft Accelerating Charge 2.0 ml.
Updraft Accelerating Charge 1.9 ml.

FIG. 12—COMPARATIVE PERFORMANCE OF UP AND DOWNDRAFT INDUCTION-SYSTEMS

measured as precisely as variations in other engine-factors warrant. This instrument is simple in operation and moderate in cost.

(3) Technique of operation and methods of analysis have been developed, enabling the maximum results to be obtained from each test.

(4) The effect of fuel volatility is shown to be qualitatively independent of engine design.

(5) The effects on acceleration of increasing (*a*) the heat applied to the manifold, (*b*) the fuel volatility and (*c*) the accelerating charge are similar, all three acting to increase the acceleration at low engine-speeds. However, if the supplied mixture is as rich as that which gives maximum power, heating the manifold or increasing the volatility of the fuel will increase the acceleration at low engine-speeds. However, if the supplied mixture is as rich as that which gives maximum power, heating the manifold or increasing the volatility of the fuel will increase the acceleration at low speeds but will decrease it at higher speeds.

(6) By properly proportioning the quantity and rate of injection of the accelerating charge, together with the use of the carbureter setting giving maximum power at constant-speed operation, it is possible to realize practically the computed maximum-acceleration over the entire speed-range.

(7) The total induction-system surface to be wetted is a determining factor in fixing the quantity of accelerating charge required to produce optimum acceleration-performance, and, therefore, when no accelerating charge is used, in limiting the acceleration performance.

THE DISCUSSION

A MEMBER:—Can Mr. Bruce tell us what difference in acceleration could be detected in a car on the road? I do not know whether he could express it in, say, the time to accelerate from 5 to 15 m.p.h. With the difference of 0.5 sec. on his chart, is that important in actual car-performance?

CLARENCE S. BRUCE:—I think Mr. Birdsell drew certain conclusions on that. From this test-car work, on which we showed some slides, he concluded that no difference due to fuel volatility would be found on the road but that in laboratory tests engine acceleration did show marked differences. I do not know of any method of timing the acceleration on the road which will give us enough time points to plot an acceleration curve, as about six observations per second would be required. The timing fork would not stand the vibration, as it operates irregularly when a vibration is imparted to its mounting. I believe that getting precise and reproducible engine-acceleration measurements with a car on the road is almost hopeless. The time required to go from one speed to another can be determined, but so far as engine conditions or setting acceleration charges are concerned, I do not think it can be done accurately enough to be of any value in research work.

A MEMBER:—I think you misunderstood the question. What I wanted to know is in connection with Fig. 12 where the maximum difference was 0.5 sec. Could you take that equipment and put it on the car and actually go out on the road and find that difference?

MR. BRUCE:—We cannot put this equipment on a car. That 0.5 sec. shown is the difference between acceleration curves.

A MEMBER:—You could not tell whether the car picked up or not?

MR. BRUCE:—I do not think you could tell any difference at all, because the curves could not be obtained on the road.

DONALD B. BROOKS[16]:—Possibly some work that we did about a year ago at the Bureau of Standards may answer that question. We took the time required for a number of cars selected at random among the Bureau cars to go from a standing start a distance of 160 ft. through all the gears. A number of what are usually called popular-type cars were in that group of the latest models, and one of them had an accelerating pump, while the others did not. That car seemed to have a decidedly better performance on the road than the others. The difference in time required to go 160 ft. was 6.0 against 6.2 sec., and that 0.2 sec. was apparently enough so that the better performance of this car could be detected by the driver.

C. H. TAYLOR[17]:—Have any experiments been made on the influence on the inside surface of the manifolds?

MR. BRUCE:—So far as I know, no work has been

(*Concluded on p.* 319)

[16] S.M.S.A.E.—Automotive engineer, Bureau of Standards, City of Washington.

[17] M.S.A.E.—Consulting engineer, Bendix Brake Co., Detroit.

The Packard Diesel Aircraft Engine

Discussion of L. M. Woolson's Detroit Aeronautic Meeting Paper[1]

THIS is the first description that has been released of the Diesel radial air-cooled engine concerning which a great deal of curiosity has been shown. The author describes the many radical features of design that resulted in producing an engine which operates at 2000 r.p.m. on domestic furnace oil, has a compression ratio of 16:1, air compression of 500 lb. per sq. in., compression temperature of 1000 deg. fahr., fuel pressure of the order of 6000 lb. per sq. in., develops 225 hp. at 1950 r.p.m. and weighs 2.26 lb. per rated horsepower.

Airplanes powered with this engine have been climbed to an altitude of well over 18,000 ft. without any special equipment. The mystery of the starting means is dispelled with the statement that a conventional type of starter used successfully with gasoline aircraft-engines is employed, supplemented with a special means for supplying heat to the fuel in below-zero temperatures.

Among the points brought out in the discussion are patience displayed by the engineers in developing the engine, elimination of the fire hazard will promote flying, ability to use crankcase oil as an emergency fuel, possibilities of the Diesel as an automobile powerplant, and wear due to dirt being sucked in through the inlet valve.

In a written discussion submitted after the meeting, Leigh M. Griffith compares the results obtained with those from other engines here and abroad and suggests placing a limit on the maximum combustion-pressure. In this connection he says that securing high brake mean effective pressure and low fuel-consumption at moderate maximum-pressures primarily are matters of control of rate and character of fuel injection. He is strongly impressed with the advantages of the two-stroke Junkers engine as compared with the four-stroke Packard and thinks future development will tend more toward the two-stroke Diesel.

CHAIRMAN CARL B. FRITSCHE[2]:—Captain Woolson has given us an exposition of a new-type aircraft-engine, which I think constitutes the most important advance in aircraft-engine design that has been made since the World War.

With regard to his estimate of economy of 20 per cent increase in efficiency of fuel, I could name at least a half-dozen airlines today that by having this increased efficiency translated into payload would rapidly change from red-ink to black-ink operation. This will mean an increase of 20 per cent in range or an increase of 20 per cent in payload, all of which will help to bring the cost of operation down, something we must do to put commercial aviation on a practical, commonsense basis.

One lesson that we must draw from Captain Woolson's experimental research is patience. I think that every aircraft enterprise in this Country has been guilty of a gross sin in trying to combine experimental work with actual production. Such procedure is unsound from the standpoint of economy, is unsound from the standpoint of scientific endeavor, does not produce good workmanship and is an indication of amateurish attempt. Flying with an engine or testing an engine for an equivalent of 250,000 miles is an indication of the type of patience that gets real scientific results and in the long run helps to solve these many problems.

This matter of safety with respect to fire is something we are all concerned with. A man who will not admit that he is fearful of fire in a forced landing of an airplane filled with ordinary high-volatile fuel is not honest. We all recall that every preacher and even the savages in Africa hold up being burned alive as the worst punishment of man. Anything that will help to eliminate that hazard is something that will help to increase flying.

QUESTION:—Is the Packard Diesel a real Diesel as Dr. Diesel's patent would define it, or is it a modification of a solid-fuel type?

L. M. WOOLSON:—I cannot say that I am thoroughly familiar with all of Dr. Diesel's patents, but the engine is a real Diesel in that it does not rely on hot-spots for its operation, such as a semi-Diesel of the hot-bulb type.

QUESTION:—In view of the low operating-costs with fuel oil in Diesel operation, what do you think are the future possibilities of a continued fuel-oil supply, taking into consideration the new patents relative to cracking processes to reclaim practically all the crude?

MR. WOOLSON:—Sooner or later we can take all the fuel oil and turn it into gasoline, but, of course, to do that considerable heat has to be applied which involves considerable expense. While being able to effect the economies that we now have with the Diesel engine by purchasing an oil as low as 8.5 cents or even 4 cents per gal. is very nice, eliminating the fire hazard for one thing and economizing in the weight of the fuel we have to carry are of major importance. So, even if the fuel oil is more expensive, it still would not interfere with the success, or rather the desirability, of the Diesel aircraft-engine.

QUESTION:—In case of emergency could you resort to crankcase oil for the Diesel aircraft engine?

MR. WOOLSON:—The engine would run on any hydrocarbon oil; crankcase oil would be very fine.

QUESTION:—Is the Heywood starter applicable to the Diesel engine?

MR. WOOLSON:—The Heywood starter is applicable, of course, to the Diesel engine. My reason for preferring the inertia starter was not based on anything other than that we have found that it meets the needs of the engine a little better than anything else.

QUESTION:—Does this design contain anything basic which could not be incorporated in an engine develop-

[1] The paper was published in the April, 1930, issue of the S.A.E. JOURNAL, p. 431. Mr. Woolson, who was killed 15 days after the presentation of the paper, was a Member of the Society and aeronautical and research engineer, Packard Motor Car Co., Detroit. The abstract that preceded the paper when it was published is reprinted for the convenience of the reader and is supplemented by a brief summary of the discussion.

[2] M.S.A.E.—President, Aircraft Development Corp., Detroit.

ing less than 100 hp. and weighing less than 300 lb.? This size probably constitutes the greatest potential market.

MR. WOOLSON:—I do not agree with the writer of this question as to that size constituting the greatest potential market. I have watched the general development, and we have gone through cycles in airplane powerplants just the way we have in automobiles. We have gone all of the way up to 265 hp., but we have finally come down to think that 80 hp. is about right for good-sized automobiles. I think that modern airplane engineers are of the opinion that 50 hp. per passenger is about the right figure for airplanes and, as far as getting 100 hp. is concerned, all we have to do is to knock off some of these cylinders and we have it.

QUESTION:—If injection carburetion on gasoline engines proves successful, will two-cycle engines then be used and what would be its advantage?

MR. WOOLSON:—I presume this question refers to the method of running a two-cycle engine by injecting an atomized charge of gasoline after the ports are closed, which is an economical way, of course, to operate a two-cycle engine. On the other hand, the limitation of the two-cycle engine-operation is more a matter of flexibility to my mind, and even if we have a good injection system, this does not mean that the engine will idle and throttle down nicely unless we are able to stratify the charge much better than has yet been accomplished.

QUESTION:—What is the possibility of using the Packard Diesel as an automobile engine?

MR. WOOLSON:—I am sure it could be used in automobiles, but gasoline engines of the type we are using today are unquestionably more suitable. The requirements of automobile powerplants are altogether different from airplane powerplants. No comparison at all can be made, and, while the Diesel engine can be, and has been, put in the automobile, none of us think that a thing like that is coming in the near future.

QUESTION:—What is the lubricating-oil consumption of this engine as compared to the conventional gasoline engine?

MR. WOOLSON:—We are running between 0.03 and 0.05 lb. per hp-hr. At present we can get anything we want. It is just a matter of connecting-bearing clearance, and we prefer to use a little more oil rather than a little less. Spare the oil and spoil the engine, or something like that. One thing to remember in the case of the Diesel is that we do not have to worry about the oil consumption. Keeping the oil consumption down in aircraft engines is necessary to keep the spark-plug from fouling and, if we put enough oil in the engine, it will run without any fuel at all. When we started this work, one of the first experimental engines was running on an electric dynamometer, and somebody in the powerhouse decided to shut off the current. The dynamometer quit dynamometering, the engine went up to 3500 r.p.m., which was the limit of the dynamometer, and continued to run long after I shut off the fuel and the only way we stopped that engine was with a 2 x 4 and a coupling.

QUESTION:—Are not the bottom cylinders subject to excessive wear due to dirt being sucked in through the inlet valve?

MR. WOOLSON:—Dirt does not do any engine much good. We allow a little passage for the air to separate the dust which is effective to a marked degree; that is, the air, as it goes into the cylinder, has to make a right-angle turn, whereas most of the air, being drawn back by the suction produced by the exhaust pipe, is turning in the direction of the slipstream. We have no trouble with cylinder wear that is due to dirt, but perhaps we have not been running where the air is dirty enough.

QUESTION:—Do the cylinder bases leak oil?

MR. WOOLSON:—No. We have a rubber packing-ring that we have used on all our aircraft engines, and that really is the only way to my mind to make a tight job. The cylinder fits right on the crankcase, a metal-to-metal contact, and a small packing-ring fits into the crankcase and makes a complete oil seal.

QUESTION:—Is the tension in the hoops distributed evenly over all the cylinder bases?

MR. WOOLSON:—It certainly is. The turnbuckles are drawn up with a wrench 3 ft. long and that persuades the hoops to go close.

Comparison of Results with Other Engines

LEIGH M. GRIFFITH[3]:—This paper is very interesting and invites discussion on a number of points. The claim that this engine greatly extends the operating speed of the Diesel is rather too strongly drawn, however, and it may be well to invite attention to the fact that the ability of the Diesel to operate at high rotative and piston speeds, with brake mean effective pressures approximating 100 lb. per sq. in. and fuel-consumption rates under 0.42 lb. per hp-hr., has been repeatedly demonstrated in the past. The fact that these early results have not been advertised in this Country has probably prevented most engineers not directly interested in such developments from appreciating that the high-speed Diesel has been at hand for several years. Only the support of such a well financed and persistent experimental organization as has produced the Packard engine has been lacking or we would have realized the aircraft Diesel years ago.

Early in 1922, the National Advisory Committee for Aeronautics Research Laboratory at Langley Field, working with a standard Liberty cylinder which was obviously ill-adapted to the purpose, obtained results that, when translated to a normal mechanical efficiency of 85 per cent for multi-cylinder engines, show 99 lb. brake mean effective pressure at 1750 r.p.m (2040 ft. per min.) with a fuel consumption of 0.42 lb. per b.hp-hr. Working with its Universal Test Engine, the combustion-chamber of which was slightly better adapted to fuel-injection operation, that laboratory in 1925 or 1926 obtained 112 lb. brake mean effective pressure at 1500 r.p.m. (1750 ft. per min.) with a fuel rate of 0.39 lb., as corrected to 85 per cent mechanical efficiency.

The British Royal Aircraft Establishment Laboratory about 1921 secured 120 lb. brake mean effective pressure at 1200 r.p.m., its work having been subject to the specific limitation of 800 lb. maximum pressure as a basic condition. The 8 x 11-in. single-chamber 20-T engine gave 107 lb. brake mean effective pressure at 1200 r.p.m. (2200 ft. per min.), with a fuel rate of 0.44 lb. and maximum pressure of only 650 lb. At 800 lb. maximum pressure, the brake mean effective pressure rose to 112 lb. and the fuel consumption dropped to 0.40 lb. The mechanical efficiency was about 82 per cent.

The Junkers two-stroke opposed-piston Diesel engines have for several years been yielding high brake mean effective pressure at high speeds with low fuel-consumption. Although two-stroke operation at high speed is ordinarily considered to be very difficult, Junkers had

[3] M.S.A.E.—Vice-president and general manager, Emsco Aero Engine Co., Bell, Calif.; now consulting engineer, Los Angeles.

an aircraft engine of this type operating in his laboratory in 1915. Performance data of this engine were apparently never published. The two-cylinder 3.15 x 11.81-in. automotive Junkers in 1926 gave a specific fuel-consumption of 0.41 lb. at 88 lb. brake mean effective pressure and 1500 r.p.m. (2950 ft. per min.), the maximum pressure not being stated. The latest model of Junkers aircraft Diesel has been in flight operation since February, 1929, and is stated to give 91 lb. brake mean effective pressure at its normal speed of 1500 r.p.m. (2070 ft. per min.), with fuel consumption under 0.38 lb., while at its maximum speed of 1700 r.p.m. (2340 ft. per min.) it gives 94 lb. brake mean effective pressure with a specific fuel-rate under 0.40 lb. As the design of this engine is very difficult from the standpoint of structural weight, Junkers' achievement of a weight of 2.8 lb. per hp. is a remarkable proof of the inherent advantages of the two-stroke.

Of special interest in this connection are the performance figures given by H. R. Ricardo[4]. Working with a 5.50 x 7-in. sleeve-valve engine, he secured a fuel consumption of 0.385 lb. at 90 lb. brake mean effective pressure and at the very high speed of 2200 r.p.m. (2570 ft. per min.), with a maximum pressure of 850 lb. The mechanical efficiency was only 74 per cent, due to the proportionately higher losses in a single-cylinder engine. With a normal value of 85 per cent, such as would be experienced in a multi-cylinder engine, the fuel rate would drop to 0.334 lb. and the brake mean effective pressure rise to 104 lb. for the same combustion conditions and indicator card. The maximum brake mean effective pressure secured was 108 lb. at that speed. With a previous engine of the same size, but designed for lower speeds, he obtained 119 lb. brake mean effective pressure at 1300 r.p.m. (1520 ft. per min.), with a mechanical efficiency of 83 per cent. The fuel consumption was constant at 0.355 lb. throughout the range of 70 to 100 lb. brake mean effective pressure, the maximum pressure at 90 lb. being 800 lb. That the combustion was efficient is shown by the low specific consumption of 0.29 lb. per i.hp-hr. for both engines.

Maximum Combustion Pressure Should Be Limited

The performance of the Packard as given figures 93 lb. brake mean effective pressure at 1950 r.p.m. (1950 ft. per min.), but the specific fuel-consumption is not stated in the paper, except the general figure of 20 per cent less than carburetered engines. This is unfortunate, as fuel economy is most important and the high maximum pressure of 1200 lb. is presumably incurred to secure a low fuel-rate. According to a published performance chart[5], the fuel rate of this engine is 0.38 lb. at 1950 r.p.m. and full load, and falls to 0.35 lb. at 1700 r.p.m. and two-thirds load point on the propeller-load curve. This is a very fine result and indicates a fuel saving of about 35 per cent as compared to a carburetted engine at a similar cruising load. The official consumption as given in the Packard Diesel catalog, however, is 0.46 lb. at full power and 0.40 lb. at cruising, the load and speed not being stated. These last figures check roughly with the 20 per cent saving mentioned in the paper.

Inasmuch as the weight of any structure is closely determined by the maximum loads that will be imposed, and as the aircraft engine can be no exception to this law, the majority of engineers working with the high-speed Diesel have become convinced that the best over-all results will follow the placing of some limit on the maximum combustion pressure. Packard has allowed this pressure to reach a value of about 1200 lb., thereby making its design problems that much more serious. The fact that the weight has been brought down to 2.26 lb. per hp. is evidence of the value of the unusual design features that have been adopted. Obviously, however, if the maximum pressure had been kept down to 800 lb. a considerable reduction of structural weight could have been effected. The designers considered it necessary to adopt unusual but admittedly clever expedients to counteract the great torque irregularity caused by the excessive maximum pressure. The adoption of the lower pressure of 800 lb. would have eliminated the necessity for the pivoted spring-mounted counterweights and the shock-absorbing rubber propeller-drive.

The author states that "a high-speed Diesel engine suitable for aircraft would entail these high pressures," an opinion that is based upon incorrect analysis of the operating characteristics and that is directly disproved by both laboratory tests and service experience. The use of such high cylinder-pressures is in reality merely the quick and easy way to secure high-speed operation and can be justified only from this standpoint, although the resulting increased difficulty in keeping the engine light enough was a strong offsetting factor.

The securing of high brake mean effective pressure and low fuel-consumption at moderate maximum pressures is primarily a matter of control of rate and character of fuel injection. The element of turbulence or charge circulation undoubtedly enters into the problem but only to a relatively limited extent. To secure a predetermined rate and character of fuel injection requires that the whole injection-system be most carefully designed to yield that result. The problem is not a simple one as yet. However, to apply the effort in that direction, rather than in the struggle to absorb unnecessarily high maximum pressures, is certainly better since the final result will be distinctly superior. This point of view assumes greater importance as the sizes of cylinders increase, as they surely will in the natural course of development of the large aircraft-engines of the future, even though accepting a slightly higher fuel-consumption rate in order to keep the maximum pressure within the limit set by considerations making for the best over-all results may prove necessary.

The author places considerable importance upon a high degree of turbulence, as a means of accelerating the commingling of fuel and air. While the evidence is not conclusive, I am inclined to believe that the necessity for high turbulence is proof that the spraying and distributing functions of the injection system are unsuited to the combustion-chamber form or that the time-rate control of injection is incorrect. Simple forms of combustion-chamber have been proved to give excellent results, with no special means of producing turbulence. In fact, the high turbulence sought and presumably achieved in the Packard may be largely responsible for the high maximum pressures.

Regarding the superiority claims for the simple combination of fuel pump and injection valve into one unit, without connecting piping, the author entirely overlooks

(*Concluded on p.* 319)

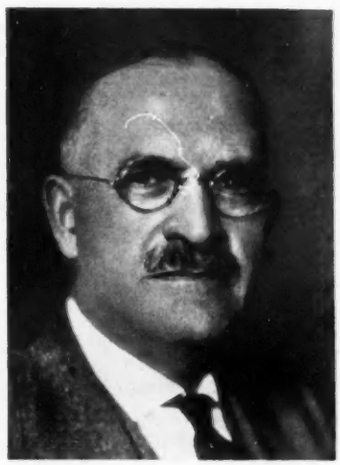
[4] See *Automobile Engineer*, April 1930, p. 151.

[5] See *Aviation*, April 5, 1930, p. 688.

Small Diesel Engines

Semi-Annual Meeting Paper

By H. D. Hill[1]



Attention is drawn to the difference in method of procedure necessary in developing large and small Diesel engines and to the greater obstacles met in systems injecting the charge directly to the cylinder in comparison with those employing precombustion-chambers. The antechamber fuel system used in the Hill engine is described as performing three functions: (*a*) to ignite and eject rich fuel gas into the main combustion space early in the combustion stroke; (*b*) to feed the cylinder combustion with air from the upper portion of the antechamber after the main part of the fuel charge has been ejected from the chamber; and (*c*) to cause violent turbulence and complete mixture of the charge by the large stream of gas issuing from the antechamber. Only the first of these three functions is accomplished by the ordinary precombustion-chamber. A recently developed automotive-type engine is described. Discussion of this paper and C. L. Cummins' paper on Diesel Engines for Automobiles will be found beginning on p. 290 of this issue.

PRINCIPLES used in the development of solid or hydraulic fuel-injecting systems for large slow-speed Diesel engines require different treatment to make them adaptable to small high-speed engines. Fuel systems which show good results in cylinders over 8 in. in diameter may not be simply reduced in size and capacity to give satisfactory results in cylinders of 5 in. or less diameter operating at twice the speed.

Many obstacles beset such a course, among them being the greater ratio of heat-radiating surface to cubic volume; the smaller combustion space, with increasing difficulty in keeping the fuel off the cooled surfaces; the necessity for greater accuracy in metering the fuel in the minute charges; and a host of other difficulties more or less serious, depending on the characteristics of the system under consideration.

For the purpose of this discussion, the present-day small-engine fuel systems will be divided into two general classes: (*a*) those in which the fuel is sprayed directly into the cylinder, and (*b*) those in which the fuel is first sprayed into an antechamber.

Fig. 1 illustrates two commonly used forms of cylinder combustion space into which the fuel is sprayed directly. Spray valves having a number of orifices are generally used with direct-to-cylinder fuel systems, although single-orifice spray valves are sometimes used with the flat cylindrical space shown in the upper of the diagrams. Very fine atomization of the fuel is necessary to obtain proper mixture of air and fuel, and this requires fine orifices and high injection pressure.

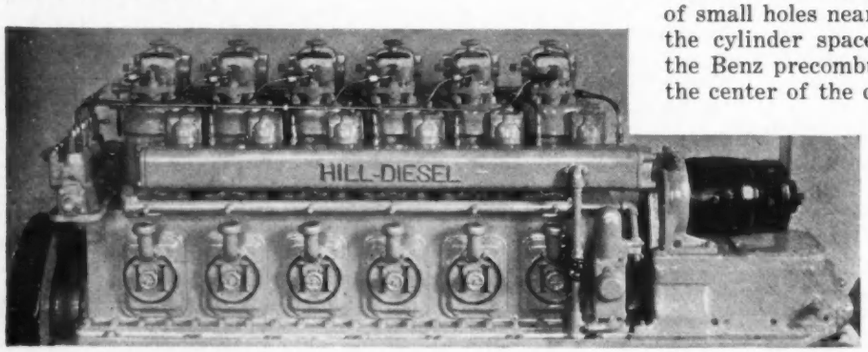
Orifices as small as 0.004 in. in diameter are sometimes used, making careful filtering of the fuel necessary to remove as much of the foreign matter as possible. Hydraulic pressures as high as 8000 lb. per sq. in. are used to obtain the degree of atomization required. The penetration of the finely divided fuel into the dense air of compression is not sufficient to cause good distribution of the fuel in the air and bring each droplet into contact with its required portion of air to promote complete combustion, and other means of creating turbulence are provided.

Turbulence is promoted in some engines by shielding one side of the inlet valve; in others, the air-inlet passage is given a venturi-like form which directs the air into the cylinder in a circular current. Careful attention is given to the form of the spray jets to avoid contact of the spray with cooled surfaces, as any fuel deposited on the walls of the combustion space forms carbon and contributes to a smoky exhaust.

Two conventional types of precombustion chamber are illustrated in Fig. 2. That at the left is the Deutz, located at the side of the cylinder and having a number of small holes near the bottom which communicate with the cylinder space. The diagram at the right shows the Benz precombustion-chamber, which is located near the center of the cylinder and has a number of holes in the bottom arranged to deliver the fuel in a wide-angle cone over the area of the cylinder. Both of these systems use a glow-plug for starting at low temperatures.

Fig 3 shows the general arrangement of the antechamber used in the Hill engine. This antechamber is placed at an angle in the cylinder head and is completely water-jacketed.

[1] M.S.A.E.—Vice-president and general manager, Hill Diesel Engine Co., Lansing, Mich.



MARINE-PROPULSION ENGINE, WITH REVERSE GEAR AND LIGHTING GENERATOR

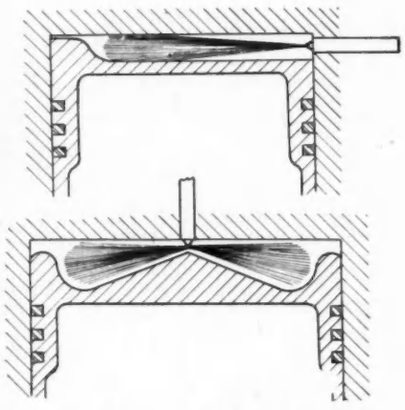


FIG. 1—COMBUSTION-CHAMBERS OF TYPICAL DIRECT-INJECTION DIESEL ENGINES

The Upper Diagram Represents the Dornier Engine and the Lower Is of the Bessemer Engine

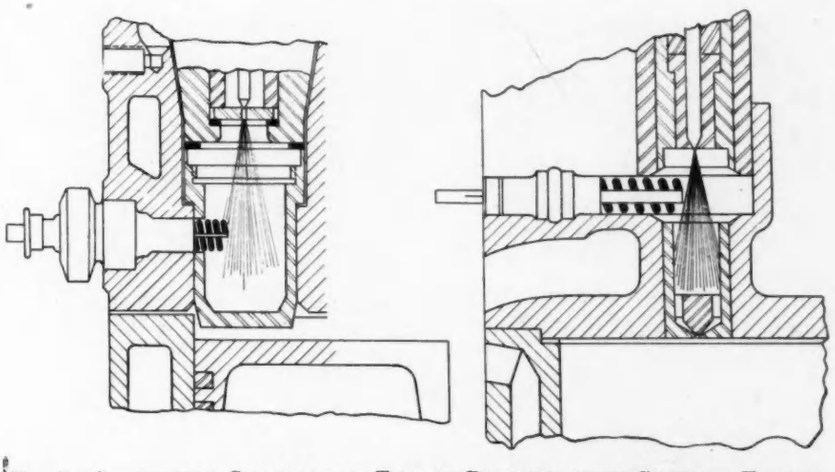


FIG. 2—COMBUSTION-CHAMBERS OF TYPICAL PRECOMBUSTION-CHAMBER ENGINES

The Deutz Engine, at the Left, Has Its Precombustion-Chamber at One Side, While That of the Benz Engine, Shown at the Right, Is Located at the Center of the Head

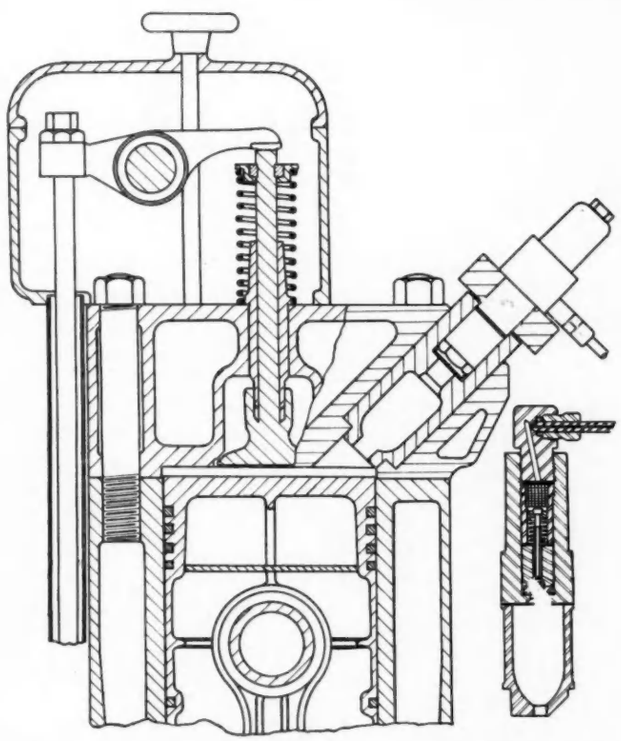


FIG. 3—CYLINDER-HEAD CONSTRUCTION OF HILL ENGINE

The Antechamber Is Placed at an Angle at the Side of the Cylinder, with Which It Communicates Through a Large Opening. The Fuel Nozzle, at the Upper End of the Chamber, Is Shown in Detail in the View at the Right

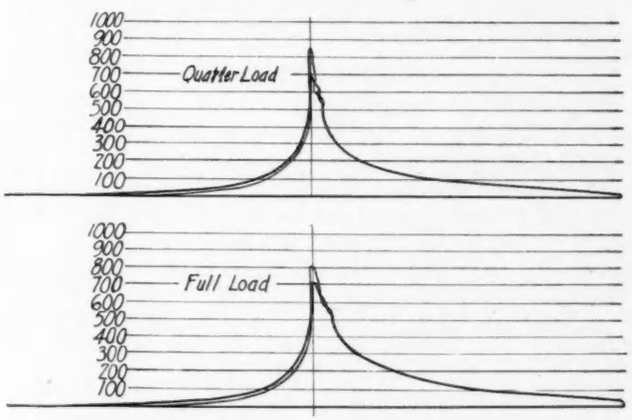


FIG. 4—PRESSURE DIAGRAMS OF HILL ENGINE

The Upper Diagram Represents Operation at One-Quarter Load and the Lower Diagram at Full Load. Light Lines Show the Pressure in the Antechamber, and Heavy Lines Show the Pressure in the Main Combustion Space

A single large hole in the bottom conducts the fuel to the cylinder. The principles involved in this type of antechamber are somewhat different from those of the precombustion-chamber shown in Figs. 1 and 2. The entire volume of air in those chambers is charged with fuel, and combustion proceeds until the air is consumed, leaving the chamber filled with a rich mixture of spent air and fuel, most of which will be forced out by the pressure rise due to the precombustion. Whatever combustion begins in the precombustion-chamber is damped out as the burning mixture passes through the

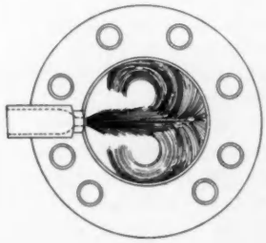


FIG. 5—MARKINGS ON HILL PISTON-HEAD SHOWING PATH OF FUEL SPRAY

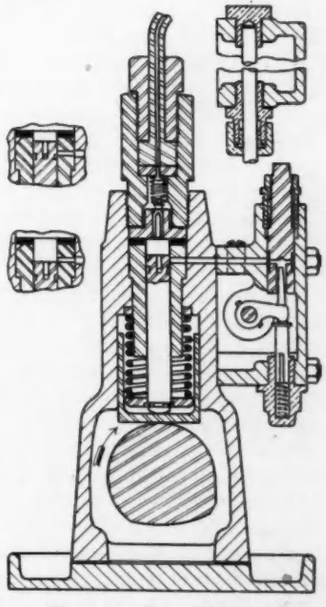


FIG. 6—END SECTION THROUGH FUEL PUMP

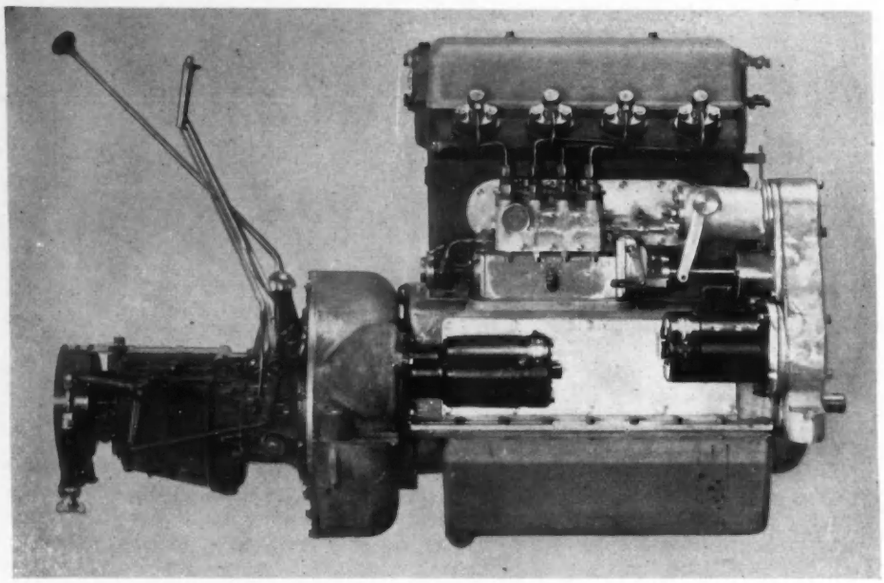


FIG. 7—AUTOMOTIVE POWERPLANT WITH 3½ X 6-IN. ENGINE

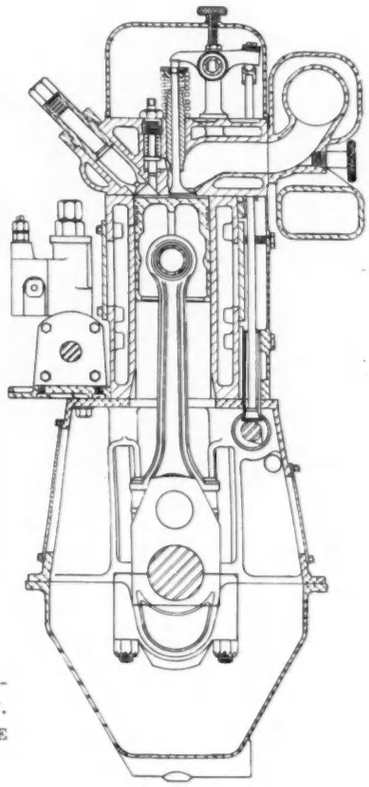


FIG. 8—END SECTION OF 3½ X 6-IN. AUTOMOTIVE-TYPE ENGINE

several small holes, by the same principle that is used in screening the miner's lamp, and must be reestablished in the cylinder to complete the combustion. At the end of the exhaust stroke there is still a quantity of partly burned gas in the precombustion-chamber, and this sometimes causes preignition during the next compression stroke.

A fine fuel spray is not necessary in the antechamber shown in Fig. 3; and therefore a large single orifice is used, with an injection pressure of about 1500 lb. per sq. in. The form of the chamber is such that the greater portion of the rich mixture is forced into the cylinder during the first part of the expansion stroke of the engine, and further expansion feeds the burning mixture in the main combustion space with the unimpregnated air from the upper part of the antechamber. The large single hole in the bottom of the chamber allows the combustion to proceed from the chamber into the cylinder without damping effect, and the combustion is therefore more rapid than with multiple outlets.

Fig. 4 illustrates the pressure differential which occurs in a 5 x 7-in. cylinder and its antechamber. The upper diagram represents conditions with about 25-per cent load, and the lower shows full-load conditions. The large stream of gas, under the pressure indicated, penetrates to the opposite side of the cylinder, causing violent circulation throughout its area.

Soot markings on the cylinder-head and piston after a few hours' run under load indicate clearly the path and extent of the circulation. Fig 5 was drawn from a typical example. The path of the main stream shows brown markings, indicating the high temperatures, then gradually darkens to dead black at the branches. After a period of operation under an overload, the surplus fuel will be deposited at the ends of the branches in the form of carbon, indicating that the fuel does pass through the air field.

We believe these characteristics place this system in a class apart from other precombustion-chamber systems. Preignition of the fuel is only one of its three important functions, the second being to feed the fuel with air after ignition and the third to cause turbulence. We believe, therefore, that it may be more properly called an antechamber system. The burning gas entering the cylinder space and contacting with the walls does not deposit carbon or cause a smoky exhaust.

Fuel Injection and Governing

The fuel valve used with this system is of the closed type, having a spring-loaded check-valve opening with the pressure and a spray button with a single round straight hole about 0.020-in. diameter, as shown in the enlarged section in Fig. 3.

The fuel pump, shown in Fig. 6, has a cast-iron or aluminum body in which steel cylinders with lapped plungers are inserted. A port in the side of the cylinder acts as an inlet valve, admitting fuel when the plunger is at the bottom of its stroke. When sufficient pressure builds up in the cylinder during the up-stroke, the discharge valve opens and the charge passes out through the tube to the spray valve. When the groove on the plunger uncovers the port in the cylinder wall, oil passes down through the central hole in the plunger and back to the fuel reservoir by the same path through which it entered, thus relieving the pressure and stopping the discharge. The relief of the pressure in the cylinder and tubing permits the check in the spray valve to close positively and cut off further discharge or drivel.

Attached to the side of the pump body is a fuel reservoir, which houses the metering device. A constant light pressure is maintained in the fuel reservoir by a service or transfer pump. For each pump cylinder there is a tapered pin working in a hole in the end of a plug that is adjustable, so that all the pins can be made to close at the same instant. The metering pins are

(*Concluded on p.* 351)

Diesel Engines *for* Automobiles

Semi-Annual Meeting Paper

By C. L. CUMMINS[1]

EXPERIENCE with a large sedan and a roadster in which the original eight-cylinder engine had been replaced by a four-cylinder Diesel engine is recounted in the first part of this paper, including road driving and establishing an official speed record at Daytona Beach, Fla.

Then follows a description of the metering, injection and combustion processes of the Cummins engine, which are distinguished principally by the separation of the metering and injection operations so that the former is done at low pressure and the fuel is preheated and aerated before injection. Turbulence is caused and sooting of the injector orifices is prevented by the action of an air bottle in the piston-head.

Discussion of this paper and H. D. Hill's paper on Small Diesel Engines will be found beginning on p. 290 of this issue.

APPLYING a Diesel engine to an automobile has raised many interesting and unusual problems, as well as some astonishing economic results in the transporting of weight. Most of us evidently thought that the status of the gasoline engine for automotive work was thoroughly established. One evidence of this was found when I attempted to obtain a license for a Diesel-powered car. Issuing the license required much time, because the supposedly fixed and well-established rules made no provision for such a powerplant.

Another problem presented itself when application for insurance was made. The automobile department of one of the largest insurance companies, which first issued the policy, later suddenly canceled it, with the statement that the company was unfamiliar with the hazards that the Diesel engine might develop in the car. It was only after waiving numerous details that ordinary protection was obtained.

Up to date we have experimented with cars of two types, which have given us invaluable information as to what automotive requirements might be. The first car was a seven-passenger sedan-limousine which weighed approximately 6000 lb. when ready for the road. This is the car which was used in our trip to New York in January, 1930, as reported previously[2], and it was driven approximately 6000 miles. The fuel consumption varied from 25 to 35 miles per gal. according to the speed and the number of delays in traffic. The car was geared 2½ to 1 and aside from being a little sluggish on the pick-up from 0 to 20 m.p.h., the performance was practically the same as with the powerplant originally used in the car.

The engine had four cylinders of 4½-in. bore and 6-in. stroke and was designed to operate normally at a maximum of 1000 r.p.m. The regular governor equipment was left on the engine—adjusted to allow about 1200 r.p.m., which gave the car a top speed of 52 to 55 m.p.h. The original transmission and clutch of the car were retained and the engine as used in the first car was not modified. As the engine was designed primarily for marine service and complied, as far as practicable, with the specifications of both Lloyd's and the American Bureau of Shipping, it was approximately 400 lb. heavier than the one removed from the car. No difficulty whatsoever was experienced in the handling of the car because of its added weight and, although many hundreds of miles were driven on snow and ice-covered pavement, the car seemed to be perfectly stable.

Performance of Diesel Car Was Normal

Almost every conceivable traffic condition was encountered during the drive from Indianapolis to New York, from the long, straight stretches across Indiana and Ohio to the hilly, crooked roads of Eastern Ohio and Western Pennsylvania. The entire stretch of mountainous Pennsylvania was buried in snow and ice, except for a few spots in the valleys. The temperature ranged from considerably below zero to about 70 deg. fahr., which was encountered during the week of the Automobile Show in New York. No radiator fan could be used, for lack of space, yet it was necessary to cover up from one-half to two-thirds of the original radiator. The water temperature, which was taken at the hottest point, ran normally around 90 deg. and never exceeded 120 deg. in the hardest mountain pulls.

The engine was sufficiently flexible to meet the traffic conditions found in New York, Philadelphia, Baltimore and other cities en route. The performance seemed perfectly normal, from the outside, as no one, either drivers or traffic officers, gave us a second look. The exhaust at all times was better than the average of the gasoline cars which we were passing and not nearly as bad as many cars that were observed.

From the experience gained with the sedan, it was evident that the engine had sufficient flexibility and

[1] A.S.A.E.—President and general manager, Cummins Engine Co., Columbus, Ind.

[2] See S.A.E. JOURNAL, April, 1930, p. 512.

power to develop fairly high speed if used in a lighter model of car having a higher gear-ratio and minor changes. Consequently, we decided to install the same engine in a roadster, which weighed about 4500 lb. The difference in the handling of the car was very noticeable, the acceleration was better, and the performance, in general, was excellent. From some short test-runs which were made, we decided that a top speed of possibly 70 m.p.h. might be obtained with this car; and, as the American Automobile Association officials were to be at Daytona Beach with timing apparatus to take care of Kaye Don's attempt to break the record set up by Major Segrave, application for sanction was made and granted.

The car was driven from Columbus, Ind., to Chattanooga, Tenn., on the first day. The distance was 436 miles, and the average speed was 42 m.p.h. for this run. While in Chattanooga, we decided to climb Lookout Mountain, and the climb was made with four passengers in the car, in the high-gear ratio of 2½ to 1 with the exception of two spots which were so rough that it was necessary to drop into second gear for a short distance.

Establishing an Official Speed Record

The total distance to Daytona Beach was 1060 miles. Two fillings of the fuel tank were required, and 39 gal. of fuel were used. On arrival at Daytona Beach, the top and windshield were removed from the car and axle-drive gears were installed to give a 2:1 ratio. No changes were made in the engine, and it was unnecessary to make any adjustments in spite of the hard trip from Indiana.

Our first run for the record was made after one practice run on the beach, and we made an average in both directions of slightly less than 80 m.p.h. A tire change was then made, which had the effect of reducing the gear ratio slightly and seemed to help a little; and on Thursday, March 20, a speed of 80.389 m.p.h. was certified by the Contest Board of the American Automobile Association. This average covered a distance of 5 miles, in each direction.

The beach was so rough on the day the record was made, that Mr. Don's speed for the day was only 91 m.p.h. The car has since made 88 m.p.h., at which speed the engine was making approximately 2200 r.p.m.

The car was driven back to Columbus in record time without changing the 2:1 gear-ratio, and second gear was not needed in the mountainous section of Tennessee. It has been driven several thousand miles since its return from Daytona Beach, mostly at high speed, without any adjustments or the replacement of any parts.

The foregoing was to show concrete examples of performance with the Cummins type of engine, and the following general description will explain and illustrate the construction and principles used in the engine.

Metering Is Separate from Injection

In order to simplify and illustrate more clearly the functioning of the engine, I have divided its operation into three general stages, in the order of their occurrence, not of their importance, as follows:

(1) Metering or delivery of the fuel to the injector
(2) Preparation and injection of the fuel charge
(3) Turbulence and combustion

Experience with our earlier engines persuaded us that metering and injection of the fuel should not be combined but should be completely separate and distinct one from the other. This permits the first stage, the metering and delivery of the charge, at extremely low pressure, which makes possible the metering or measuring of the minute quantities of fuel necessary for throttling or idling conditions in a small-bore engine. By separating the metering and the injection, both functions can be accomplished under more nearly ideal conditions than in any system in which they are combined. We found that the metering of the small quantities could not be accomplished satisfactorily under pressures of 3000 to 5000 lb. per sq. in. such as are necessary in the combined method to assure penetration and breaking up of the fuel. The mechanism must be extremely well made and the adjustments must be perfect for 3000-lb. pressure. The accuracy means high cost of the parts, and the perfect adjustment calls for skilled operators.

Equal distribution of fuel under all conditions of speed and load becomes a serious problem in the multiple-cylinder engine when individual needle-valves or metering-pumps must be used, as they were in our earlier models. The needle-valve system, as indicated in Fig. 1, proved satisfactory on one and two cylinders, but it was very difficult to assure the equality of charges delivered to all cylinders when four or more were used.

This system carries the general classification of time and pressure method of fuel delivery. One common fuel-pump for all cylinders supplies fuel under pressure to a common fuel source. An individually adjusted needle-valve, spring loaded and cam controlled, is provided for each cylinder; and the various needle-valves are lifted, in correct sequence, an amount which is controllable by either governor or hand throttle. Eccentric mounting of the rocker lever makes possible changes in

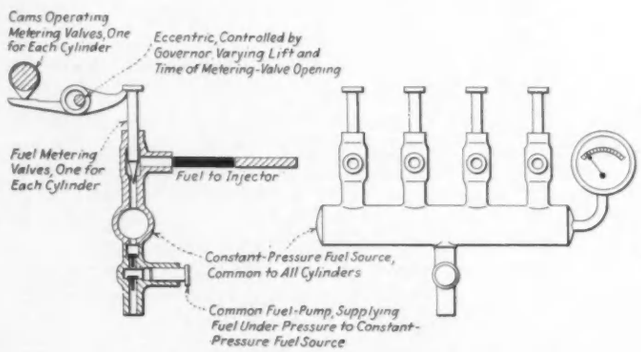

Cams Operating Metering Valves, One for Each Cylinder
Eccentric, Controlled by Governor Varying Lift and Time of Metering-Valve Opening
Fuel Metering Valves, One for Each Cylinder
Fuel to Injector
Constant-Pressure Fuel Source, Common to All Cylinders
Common Fuel-Pump, Supplying Fuel Under Pressure to Constant-Pressure Fuel Source

FIG. 1—METERING FUEL WITH NEEDLE VALVES

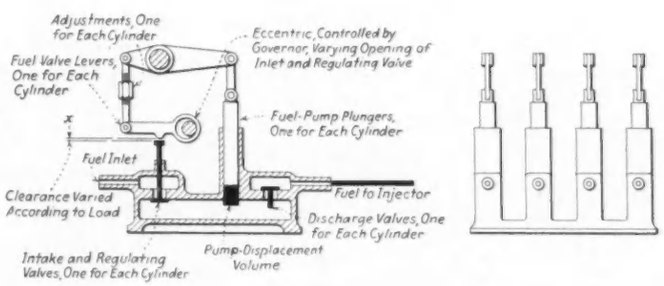

Adjustments, One for Each Cylinder
Eccentric, Controlled by Governor, Varying Opening of Inlet and Regulating Valve
Fuel Valve Levers, One for Each Cylinder
Fuel-Pump Plungers, One for Each Cylinder
Fuel Inlet
Clearance Varied According to Load
Fuel to Injector
Discharge Valves, One for Each Cylinder
Intake and Regulating Valves, One for Each Cylinder
Pump-Displacement Volume

FIG. 2—METERING PUMPS FOR EACH CYLINDER

the time and lift of the metering valves, which permit the charge to flow through the valve aperture and then to the injector. Barring the problem of individual adjustment, the system was satisfactory up to the point where the engine might be overloaded. For instance, on a 1000 r.p.m. engine, we will assume that the black portion of the fuel pipe in Fig. 1 contains the amount of fuel required at full load at 1000 r.p.m. If the engine should be overloaded and the speed pulled down to 500 r.p.m., the pressure at the common fuel source would remain substantially constant and the time would be doubled. Therefore, the charge doubles, as represented by the shaded portion of the pipe.

Separate Pumps Eliminate Time Effect

To overcome this variation, the construction as shown in Fig. 2 was adopted. In this case, an individual plunger with a fixed displacement is used for each cylinder. Metering is accomplished through the linkage shown, which opens the fuel-inlet valve. This valve is held open during the entire suction stroke of the plunger and remains open during a portion of the discharge stroke until only the amount of charge required is left in the pump. At this point the mechanism permits seating of the valve and the remainder of the fuel is forced out through the discharge valve to the injector. With this construction we eliminated the time element, or the possibility of an overcharge of fuel because of lowered engine speed. However, the problem of synchronizing the various plungers and valve mechanisms, so that each cylinder gets exactly the same amount of fuel, still remained.

Experience had taught us that the ideal fuel system should be non-adjustable, valveless and of a construction that would make impossible the delivery of a greater charge of fuel than can be burned properly in the amount of air contained in the combustion-chamber. These desirable features were all accomplished in the distributor-type fuel-pump of the fuel system which is shown diagrammatically in Fig. 3. Fuel is drawn from the tank by a gear pump and delivered to the fuel distributor. A pressure regulator maintains a constant pressure on the line to the distributor.

Arrangement of Distributor-Pump

Ports are arranged in the distributor disc so that the pressure line from the gear pump is connected, during the down stroke of the plunger, with the single plunger-pump that supplies all cylinders. As the fuel is under pressure, the pump chamber is always completely filled with fuel, regardless of the speed of the plunger. The indexing of the disc is such that fuel is admitted as the plunger is retracted, and the disc is revolved to bring into position the ports which carry the fuel to the injectors in proper sequence as the plunger is advanced during successive discharge strokes. The metering of the charge is controlled by varying the stroke of the plunger. This is accomplished by swinging the link on the arc of the lever out far enough from the zero point to give the plunger sufficient displacement for the desired charge of fuel. This link is controlled by an eccentric on which there are no adjustments, the maximum throw of the eccentric being made to swing the lever just far enough to give the maximum desired charge.

[3] See THE JOURNAL, October, 1927, p. 388.

Studying this mechanism makes it clear that the fuel is metered without dependence on valves, and the individual adjustment of plungers is eliminated by the use of one plunger for all cylinders. Controlling the maximum throw of the swinging lever removes the possibilty of overloading the engine with fuel.

This method of fuel metering and delivery is exactly parallel with the modern electrical-ignition set, in which the plunger is represented by the breaker and the distributor disc leading the fuel to the proper cylinder is represented by the distributor arm of the ignition device. Likewise, the old fuel-injection systems which we have used could be compared with electrical-ignition devices of earlier days, in which individual make-and-break spark-plugs or individual spark-coils were used. The construction also might be considered to be similar to an engine in which individual carbureters were used for each cylinder.

With our present method of metering and delivery of fuel, it is found that greater horsepower and lower fuel consumption are obtained than with the older systems, as each cylinder is doing exactly the same amount of work. The exhaust from engines using this type of pump is as perfectly balanced as in any high-grade gasoline-engine and is much cleaner than formerly, when one cylinder might be getting an excess of fuel, which would cause a smoky exhaust.

Preparation and Injection of Fuel

The second stage of operation, covering preparation and injection, is most important to the proper functioning of the engine. This stage of the Cummins method has been described in THE JOURNAL[3], but some slight changes have been made since then, and it will be necessary to repeat in order to clarify this paper.

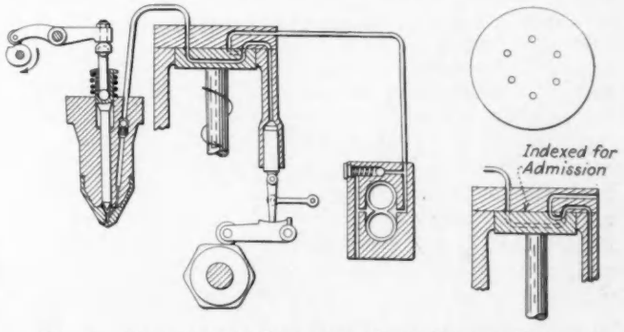


FIG. 3—DIAGRAM OF CUMMINS FUEL-SUPPLY SYSTEM

The four views of Fig. 4 represent the functioning of the injector during the four strokes of the engine cycle. During the intake stroke of the piston, the metering pump, which has been described, delivers a charge of the correct amount through a tubular connection and down through the check valve and into the annular space at the tip of the injector. This space serves as a preheating chamber for the charge of cold fuel. This space is always full of fuel. Therefore, when the fresh charge is forced into the space, a charge which has been in this space during three strokes of the engine is forced out through notches in the seat of the inner cup into the hole or port leading up into the plunger chamber. The fuel does not leak out in the cylinder because of two facts; first, the nozzles are so small that they cause the fuel to tend to rise into the unrestricted

chamber above; and, second, the plunger is being retracted during the delivery of the fuel into the chamber, producing sufficient vacuum to cause the fuel to remain in the cup. At the end of the suction stroke, the plunger is fully retracted to the position shown in the view representing compression, and a charge of preheated fuel is standing the lower end of the plunger chamber, directly over the nozzles.

The second phase is during the compression stroke of the engine, at which time a portion of the highly heated compressed air charge is forced up through the nozzles and through the pool of hot fuel. As the volume of the plunger chamber is many times greater than that of the fuel charge, a considerable dilution of this charge is accomplished. As heat and pressure cause cracking of heavy fuel fractions, there is, in reality, a cracking process in this injector, similar to that in the cracking stills used in the refineries. As the temperature and pressure in the injector are considerably higher, it can be seen that fuel oil which has previously been through the refinery cracking process can be cracked further, giving, to some degree at least, a gasoline mixture that is too rich to burn. At the end of the compression stroke, near the top dead-center, the plunger is depressed sufficiently fast to compress to a still higher pressure this rich gaseous charge in the plunger chamber. The cam is so shaped that the actual injection takes place at a predetermined rate, causing the charge to be fed into the cylinder just fast enough to prevent an excessive rise in pressure in the combustion-chamber. This comprises the third, or combustion phase of injection, occupying the last part of the compression stroke and the first part of the expansion stroke of the engine.

In the final phase, the plunger is shown seated and at rest as it is during the most of the expansion stroke and the whole of the exhaust stroke of the engine.

Fuel Is Heated After Metering

It will be seen that, after the intake stroke of the engine, the new charge of cold fuel remains in the annular space through the compression, combustion and exhaust strokes. Heat absorbed during these three strokes, plus the blasting of the heated air through the fuel charge in the plunger chamber, gives preheat or advanced preparation of the fuel charge during 720 deg. of crankshaft rotation before it is forced out into the red-hot air of the combustion-chamber. As the charge must enter the plunger chamber at a point directly over the nozzles, it does not matter at what speed the engine may be turning or what the load requirements may be; the preparation is always the same. Therefore, the

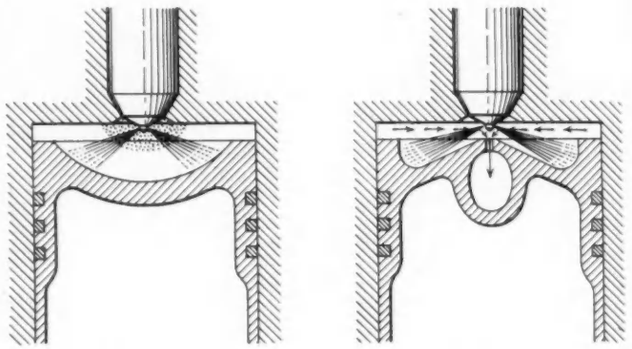


FIG. 5—COMBUSTION CONDITIONS WITH AND WITHOUT TURBULENCE CHAMBER

Zone of Very Rich Mixture, Where Combustion Is Poor, Is Shown Shaded in the View at the Left. Providing a Bottle in the Piston, with Its Orifices Pointed toward the Injection Orifices, Causes Turbulence Which Prevents Sooting of the Injection Orifices

fuel-consumption curve is virtually straight for loads greater than one-fourth load.

This method of injection has several outstanding advantages. First, the injection of a mixture in place of a solid charge of fuel assures reliable starting under cold-weather conditions. The system also has the advantage of having the minimum volume in the fuel system between the high-pressure element and the combustion-chamber, thus avoiding the expansion or breathing action of pipes and other leads. In a high-pressure fuel-system in which the high pressures are remote from the combustion-chamber some difficulty exists, which is eliminated completely in this construction.

The preparation of the charge in advance of injection naturally permits a much faster burning of the charge, which makes possible higher mean effective pressure and speed. No serious mechanical problems are involved, one simple adjustment to secure the seating of the plunger being the only adjustment in the mechanism.

The preheating also makes possible the use of a wide range of fuels. Horsepower and fuel-consumption results show that little or no difference is noticeable between fuels of 20 and 40 degress Baumé.

Turbulence and Combustion

The third and final stage includes turbulence and combustion. In the gasoline engine, a thorough mixture of fuel and air is accomplished by mixing in the carbureter and turbulence in the manifold. In the Diesel engine, a more serious problem is found. The cylinder

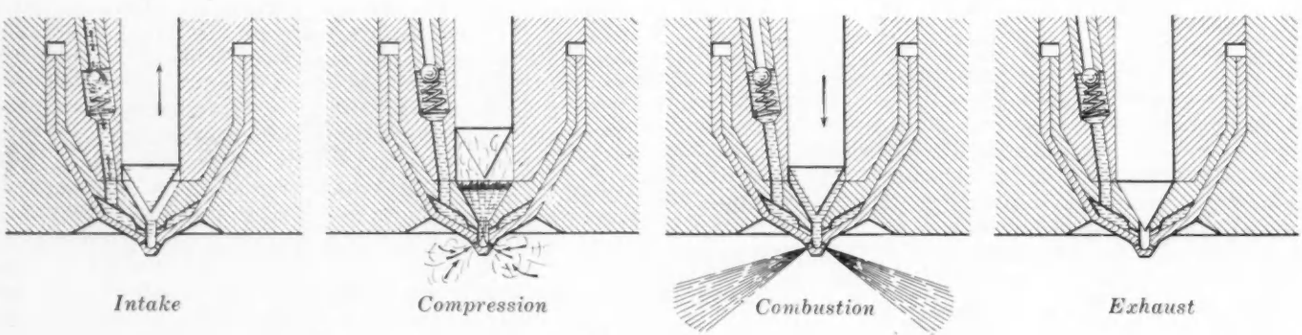


FIG. 4—CYCLE OF OPERATIONS IN CUMMINS FUEL-INJECTION SYSTEM

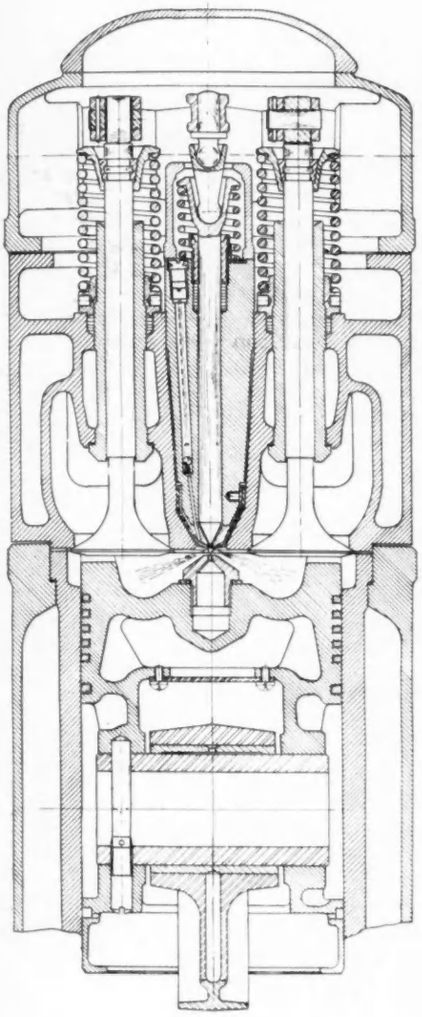


FIG. 6—CROSS-SECTION OF UPPER PART OF CUMMINS ENGINE

ly one of the means used. It is obvious that, with all of the fuel coming from a single point, an over-rich condition will exist around the end of the injector nozzles, unless some means is taken to break up this condition. The fuel in the rich zone shown near the injector in the left view is lost to combustion and the exhaust will not be clear, but the most serious disadvantage comes from the carbonizing of the end of the injector. This in time will interfere with the sprays and completely upset the performance of the engine.

The piston shown in the right view of Fig. 5 has a small bottle with open nozzles leading to the combustion-chamber. During the compression stroke, the bottle is charged with pure air at a pressure equal to that in the is drawn full of pure air, which is then compressed, and the fuel is forced into the air under pressure. It is obvious that air trapped in out-of-the-way places will be lost to combustion. Other things being equal, the horsepower of the engine is controlled to a considerable extent by the degree of the mixture of air and fuel. It is generally admitted that most Diesel engines consume considerably less than one-half of the air in the cylinder; therefore, improvement in the performance of the engine can be expected to develop along the line of utilizing more of the combustion air.

We have made some headway along this line, and Fig. 5 shows diagrammatical- compression-chamber. After injection and combustion have begun, the piston starts down on the working stroke. Soon the pressure in the combustion-chamber drops below that in the bottle. The air confined in the bottle then rushes out with force, feeding a clean stream of oxygen into this rich zone and breaking it up by better combustion. The force is sufficient to blast off any carbon formation that might occur on the end of the injector. In the actual construction as shown in Fig. 6, a small stainless-steel thimble is screwed into a drilled boss in the center of the top of the piston. The thimble is very close to the end of the injector at top dead-center. After a small fraction of the working stroke, the pressure differential is sufficient to cause a very effective blast.

Additional turbulence is developed by providing a flat annular surface at the top of the piston, brought up to the minimum clearance from the cylinder-head, which forces the air from the outer edge of the combustion-chamber toward the center, sets up a swirling motion or turbulence, and aids in the more complete utilization of the combustion air.

With the exception of the mechanism involved in the three stages of operation that have been described, the engine is of orthodox construction. It is completely enclosed, is pressure lubricated throughout and compares favorably with any overhead-valve, heavy-duty gasoline-engine only that it is a little more liberally designed in order to be adequate for 24-hr. service under full load. Figs. 6 and 7 give a good idea of the construction involved.

The engine is being produced today in sizes ranging from 4½ x 6 in. to 10 x 12 in. This largest engine has developed as high as 141 lb. per sq. in. mean indicated pressure at 800 r.p.m., or 1600-ft. per min. piston-speed. The construction and features are identical in all sizes.

We are now designing an engine that will have controlling dimensions comparable to conventional gasoline engines in motor-truck and motorcoach service. The fuel economy possible, the elimination of fire hazard, the high torque-characteristics at low speeds and the ability to start at low temperatures and take load instantly should carry the Diesel engine into the automotive field very rapidly.

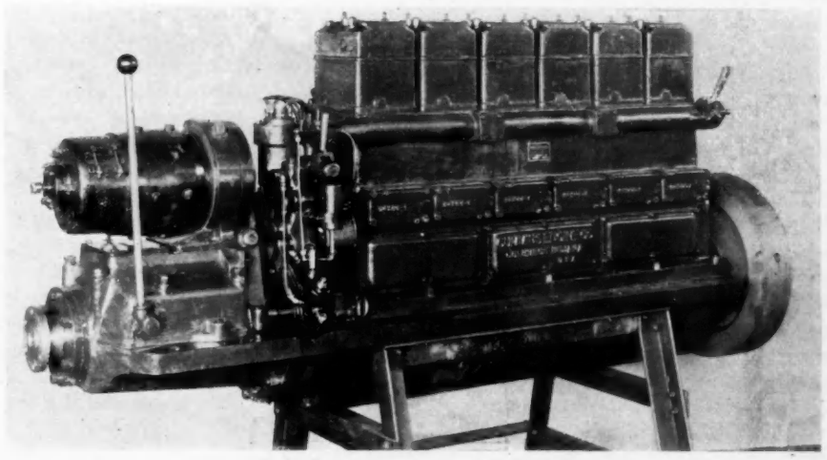


FIG. 7—CUMMINS DIESEL MARINE ENGINE, WITH REVERSE-GEAR AND GENERATOR

Discussions of Semi-Annual Meeting Papers on Diesel Engines by H. D. Hill[1] and C. L. Cummins[2]

MR. HILL'S paper on Small Diesel Engines and Mr. Cummins' paper on Diesel Engines for Automobiles were presented at the same session of the Semi-Annual Meeting and discussed jointly. The two papers are printed on the foregoing pages, and following is the discussion.

Fuel for Diesel engines was a question much discussed without definite conclusions, an oil man discounting the present situation in which the cost of Diesel fuel is low; and others saying that eliminating the cracking process required for gasoline will make Diesel oil always the cheaper fuel, and even that filtered or centrifuged unrefined oil from some sources is good Diesel fuel. The need for and difficulties in standardizing Diesel fuels were discussed.

Cost, weight, cooling, automotive applications and performance of Diesel engines received consideration. The authors agree that cold-weather starting is merely a question of provision for cranking the engine at sufficient speed, one of them setting the figure at from 175 to 200 r.p.m.

The discussion included an optimistic report by a public-service engineer based upon the operation of a motorcoach in actual service.

A. L. CLAYDEN[3]:—Every time anything about automotive Diesels is discussed or gets into the newspapers, we hear the old story about cheap fuel, in spite of the fact that everybody who knows anything about the subject is consistently hammering away at the fact that a satisfactory Diesel fuel distributed and rendered available as gasoline is today, must inevitably cost more per gallon than gasoline. H. M. Crane made remarks to that effect at the convention of the National Petroleum Association in Atlantic City last fall.

I do believe very strongly in the coming of the automotive Diesel engine. The Sun Oil Co. is closely affiliated with the manufacturers of the Doxford Diesel engine. While this company is not now making small Diesels, it probably will make them some day. The Sun Oil Co. never has made aviation gasoline; and it does not propose to do so, mainly because we are convinced that the use of gasoline as an aviation fuel is rapidly nearing its end.

The average crude-oil of the world as at present known contains potentially less Diesel fuel than gasoline; but even if fuel oil suitable for the small Diesel cost twice as much as gasoline does today, Diesel engines still ought to be able to show a lower power cost. It is absolutely unnecessary to falsify the whole picture by talking about fuel at 5 or 6 cents per gal. You have everything in your pocket already, and I hate to see the situation made more difficult for you by using these incorrect arguments.

What is most needed as a basis for standardizing Diesel fuels is to know what series of viscosities the Diesel-engine manufacturers want to standardize and whether it will be necessary to provide any lubricating quality in the fuels for small Diesel engines. It is obvious that three or four different viscosities of fuel are necessary. It is useless to specify the Baumé gravity, because a 20-deg. Baumé California fuel may have exactly the same viscosity and the same volatility characteristics as 35-deg. Baumé fuel from some other crude. The specifications must get right down to bedrock and limit the viscosity. If that question can be settled, all the other necessary fuel specification characteristics, of which the most important are probably sulphur and ash, can very easily follow. The refiners have their hands tied tight until the viscosity matter is settled.

A small amount of lubricating-oil stock included in the fuel has been found of great advantage to the life of the pumps of certain large engines. That is not a desirable thing to include, because ultimately it must add to the cost of the fuel. If the engine can be made to do without it, so much the better.

When the gasoline engine was new, gasoline could be had for carrying it away. The situation is almost the same today in regard to Diesel-engine fuels, because there is an oversupply of light Diesel fuels that are being sold at a loss to the refiner. Of course it is not a loss if considered as selling a waste product; but engine builders know that fuel of that sort should not be bought without limitations as to sulphur and ash, and such limitations require treatment.

Nothing was known about the necessary characteristics of gasoline when the gasoline automobile was in the same stage of development that the automotive Diesel engine is in today, and the Diesel-engine builder is in a better position because of the experience gained with gasoline. However, the oil maker cannot suit anyone as long as each builder of engines has a different idea as to the fuel he wants.

Fuel-Oil Is Basically Cheaper Than Gasoline

H. D. HILL:—Oil men tell me that only between 10 and 20 per cent of the present gasoline supply is distilled directly from the crude oil; the remainder is produced by cracking. This cracking process on the oil adds to the cost of the gasoline. If all the gasoline engines were destroyed today and Diesel engines substituted, a smaller number of gallons of fuel would be used and the cost of the cracking process would be saved. I am told that the oil companies would much rather sell fuel-oil without the plant and process expense of turning it into gasoline.

Can some member of the Fuels Subcommittee of the Society tell something about the work of that Committee?

[1] M.S.A.E.—Vice-president and general manager, Hill Diesel Engine Co., Lansing, Mich. Mr. Hill's paper is printed in this issue of the S.A.E. JOURNAL, beginning on p. 282.

[2] A.S.A.E.—President and general manager, Cummins Engine Co., Columbus, Ind. Mr. Cummins' paper is printed in this issue of the S.A.E. JOURNAL, beginning on p. 285.

[3] M.S.A.E.—Research engineer, Sun Oil Co., Philadelphia.

A. L. BEALL[4]:—The Committee is simply making basic investigations to determine the fundamental requirements for Diesel-engine fuel. This will probably result eventually in fuel specifications.

Mr. HILL:—Eventually there will be specifications for at least two different types of fuel, one suitable for large engines and another suitable for smaller engines.

MR. BEALL:—I should like to know what arrangements are made by Mr. Hill and Mr. Cummins for heating and filtering the fuel, particularly 20-deg. Baumé fuel, such as both Mr. Hill and Mr. Cummins mentioned, from the Eastern oil field.

MR. HILL:—It is a great advantage to have the fuel for any Diesel engine centrifuged or filtered. If it cannot be centrifuged, any one of several commercial filters will give satisfactory results. Fuels heavier than 24 deg. Baumé must be heated to flow through the small channels and tubes in the fuel system; so they can hardly become universally-used fuels, although they may be used in large stationary powerplants where heating the fuel would cause no great inconvenience.

T. J. LITLE, JR.[5]:—I should like to ask what Mr. Cummins thinks of the possibilities of Diesel engines for passenger-cars, motorcoaches and motor-trucks. What will be the ratio of power to weight and the cost per horsepower after Diesel engines are in production on the same scale as gasoline engines now are? How will Diesel cars operate as to acceleration, liability to stall and such characteristics?

C. L. CUMMINS:—I believe that the Diesel-engine makers will be able to develop engines that will weigh not over 10 per cent more than the present gasoline engines, and that the cost per pound will be about the same as the gasoline engine when made in similar quantities. I see no reason why the Diesel engine should cost much over 10 or 15 per cent more than the gasoline engine, at least the heavy-duty engine.

The engine which we have been using in a car was originally designed for only 800 r.p.m. As used at Daytona Beach, the regular 10-lb. pistons were replaced by 8-lb. pistons and the engine was run up to 2200 r.p.m. The weight of this engine is a handicap in acceleration, but only a few of the large high-powered cars that are geared very low can excel our car in acceleration.

ANDREW L. RIKER

During our trip to Daytona Beach, my brother had great difficulty in following me with a coupe of a well-known make in excellent condition. When I go back to driving my gasoline car, it feels to me as a car does in Colorado, where the altitude makes it sluggish.

MR. LITLE:—Do you use the same sort of fuel-oil that I can buy for my furnace in Indiana at about 7 cents per gal.?

MR. CUMMINS:—Yes, We have had no difficulty in getting fuel, and a supply is required so seldom that the few minutes that is required is no hardship. The practice I followed was to locate an oil company by inquiry or by consulting the telephone directory and to drive to the plant and get the tank filled free, which is not customary with gasoline engines.

No doubt the cost of Diesel-engine fuel will rise as the surplus is used. However, I believe that, if the time comes when fuel-oil is a commodity that is produced to meet the demand, oil can be bought directly from the independent producers without going through the hands of the refiners. Centrifuged crude-oil makes an excellent fuel for Diesel engines.

After returning from Daytona Beach, I received a telegram from an independent refiners' association in Texas congratulating us on the performance of the car and offering to sell us the finest crude fuel-oil for 90 cents per barrel in Texas. They sent us a barrel for testing purpose. We used it in an engine in the factory, where its performance could be checked to the best advantage, and I believe that it was the best fuel we have ever used. Why submit to the economic loss of refining, transportation and storage, when the fuel can be used as it comes from the ground? Of course the oil from some fields would not be suitable, but fortunately a large percentage of the fuel-oil produced is suitable used as fuel after being cleaned.

A. L. RIKER[6]:—Have you made accelerometer tests to determine the rate of acceleration?

MR. CUMMINS:—No; we are not automobile builders and have not the equipment for accurate tests of that sort, but we intend to have them made. All we have done is to satisfy our curiosity by putting an engine into a car and seeing what we could do with it.

MR. RIKER:—Unless the acceleration of a car with a gasoline engine can be exceeded, it will be useless to consider the Diesel engine for a passenger-car, because acceleration is a prime requirement of the automobile driver.

I noticed considerable smoke issuing from the car, as shown in the motion pictures of the Daytona Beach trials. That would need to be overcome.

I noticed that the pressure in a Diesel engine goes up to 700 lb. per sq. in. Is this engine running on a true Diesel cycle, or is the explosion pressure higher than the compression pressure?

MR. CUMMINS:—The diagram you mention was not one of our engines. Our engine has a compression of 500 lb. per sq. in., and the maximum pressure at rated load is never more than 100 lb. higher. At maximum overload of 15 or 20 per cent, which exceeds the saturation point of the air and causes the smoke which you mention, the explosion pressure is about 750 lb. per sq. in. The smoky exhaust at Daytona Beach was due to excess fuel, used to make the engine develop the maximum horsepower. The exhaust is not smoky at normal speeds and loads.

Conflicting Testimony on Radiator Capacity

FRED. M. YOUNG[7]:—According to our experience, two or three times as much radiator capacity is required for a large Diesel engine as for a gasoline engine of the same power. At that, the water temperature usually is 150 or 160 deg. fahr., when a temperature of 140 deg. is desired. I should like to know how Mr. Cummins succeeded in keeping the temperature down to 120 deg. with no fan.

MR. CUMMINS:—Cooling is related to thermal effi-

[4] M.S.A.E.—Engineer, Vacuum Oil Co., New York City.

[5] M.S.A.E.—Consulting engineer and industrialist, director of engineering, Holley Carburetor Co., Detroit.

[6] M.S.A.E.—Consulting engineer, Bridgeport, Conn. (deceased).

[7] M.S.A.E.—President and general manager, Young Radiator Co., Racine, Wis.

ciency. If an engine is out of adjustment, the temperature can run up to the danger point. In our case, we replaced a 366-cu. in. Packard engine with a 382-cu. in. Diesel engine and did the same or a little more work; yet the same radiator without a fan kept the engine cool. It seems as though something must be wrong with the efficiency of a Diesel engine that requires a larger amount of radiation than a gasoline engine of the same size, in view of the lower fuel consumption of the Diesel engine.

H. E. McCRAY[8]:—What is the fuel consumption in the Cummins engine at one-fourth, one-half and three-quarters load?

MR. CUMMINS:—At any point between one-fourth load and seven-eighths load, the fuel consumption is between 0.45 and 0.47 lb. per hp.-hr. The fuel consumption is slightly higher outside these limits.

MR. MCCRAYS—Is the speed of maximum torque controllable in an engine that is governed at 1000 r.p.m.? Can the peak of the torque curve be 700 or 800 r.p.m. and can the torque at that point be 15 or 20 per cent greater than at 1000 r.p.m.?

MR. CUMMINS:—Yes, the torque rises as the speed drops and is controllable to a certain extent.

H. L. KNUDSEN[9]:—The engine used in the Diesel car develops 86 hp. at 1700 r.p.m.

MR. MCCRAY:—Is the fuel economy reduced at that point?

MR. CUMMINS:—Yes, the economy is reduced at high speed.

MR. MCCRAY:—What brake mean effective pressures do the Cummins engines develop?

MR. CUMMINS:—The brake mean effective pressure varies between 84 lb. per sq. in. on the 4½ x 6-in. engines and 92 lb. on the 5½ x 7½-in. engines.

C. O. GUERNSEY

MR. MCCRAY:—Do you fit relief valves to the cylinders?

MR. CUMMINS:—Only on large engines on which air starting is used.

MR. MCCRAY:—What is the oil pressure at the distributor?

MR. CUMMINS:—The oil pressure depends on the resistance of the check valves and the fuel lines and varies according to the speed. The pressure is very low at low speed and it may reach 400 or 500 lb. per sq. in. at high speed. It is controllable by changing the size of the pipe-lines and check-valve openings. The distributor disc is loaded to correspond to the maximum pressure.

Experience with Various Fuels

MR. MCCRAY:—Can you get satisfactory operation with fuel that has a boiling-point or a 10-per cent distillation point below 400 deg. fahr.?

MR. CUMMINS:—Although gasoline is not suitable fuel, we have operated the engine with gasoline loaded with lubricating-oil. That might tend to cause detonation, but probably not. Detonation is caused by making the injection too early; the ideal point for injection is just later than the point at which detonation would result.

MR. MCCRAY:—What is the limiting 90-per cent distillation point for the fuel? Will fuel having a 90-per cent point above say 700 deg. cause more smoke?

MR. CUMMINS:—I cannot tell what the limitation should be of the 90-per cent point, but I believe that a fuel in which that point is above 700 would cause more smoke.

MR. KNUDSEN:—The combustion is very good with the entire crude-oil.

MR. HILL:—Some experience of ours throws light on what can be done with a fuel of low and high volatility. Five of our small engines act as auxiliaries in pipe-line pumping-stations handling Illinois and Oklahoma crude-oil. They run without difficulty on crude-oil directly from the pipe-lines, although the fuel contains a large percentage of silt. The silt is so bad that when a gate valve in the pipe-line to one of the main DeLavergne engines was removed, a short time ago, it was found to be entirely filled with the silt carried by the fuel.

B. B. MEARS[10]:—What are the difficulties in starting the engine in cold weather, and how slowly can it run when throttled?

MR. CUMMINS:—We have encountered no difficulty in starting the engine down to about −11 deg. fahr. I believe the limit would be the ability to crank the engine, and I do not know at what temperature cranking would be impossible. There was no difficulty in starting the firing. The throttling in this particular engine is none too good, because the flywheel had to be made very small for a compression of 500 lb. per sq. in. in order to get it inside the flywheel housing of the car and to accommodate the Packard clutch. Using a four-cylinder engine in place of an eight-cylinder makes the performance a little rough at low speed, but the engine will throttle down to 350 r.p.m. satisfactorily. Proper design of the flywheel and gear ratio can make the engine meet any reasonable throttling requirement.

MR. HILL:—The quality of fuel with which positive starting can be expected in cold weather depends largely on the characteristics of the fuel system of the engine. Engines feeding fuel directly to the cylinder usually start easier than antichamber or precombustion-chamber engines, and engines of the latter type having small chambers usually start harder than those with large chambers. You will notice that the Benz and Deutz engines both contain glow-plugs for starting, while our engine requires no exterior heating means for starting down to around zero deg. fahr. As Mr. Cummins has said, the only difficulty in starting is if the engine is made so stiff that it cannot be cranked at sufficient speed.

Mr. LITLE:—What is the cranking speed required for starting?

MR. HILL:—About 175 to 200 r.p.m.

C. O. GUERNSEY[11]:—There seems to be a trend toward the use of the precombustion-chamber in engines of types such as are considered for motor-trucks. Examples of this are the Hill, Benz, Sauer, Steinbecker and Deutz engines and the Bosch Acro system. Excep-

[8] M.S.A.E.—Chief engineer, Waterloo Gasoline Engine Co., Waterloo, Iowa.

[9] M.S.A.E.—Chief engineer, Cummins Engine Co., Columbus, Ind.

[10] M.S.A.E.—New York City.

[11] M.S.A.E.—Chief engineer, automotive car division, J. G. Brill Co., Philadelphia.

tions are the M.A.N. type, made in this Country by the Buda Co. and Mr. Cummins' engine, which does not conform to any of the regular classifications.

MR. HILL:—We have found that the antichamber type of engine does not require such extremely fine atomization from the injector nozzle as does the engine having direct injection. Fine atomization requires extremely small nozzle orifices and very high hydraulic pressures. These things involve very fine workmanship, and more service trouble because of clogged orifices.

MR. GUERNSEY:—I should like to ask Mr. Hill what proportion of the clearance of space of the cylinder is contained within the precombustion-chamber?

MR. HILL:—This ratio varies with different systems. The chambers of the Benz, Deutz and Steinbecker engines, for instance, are very much smaller than those in our engine, the Fairbanks-Morse and the early De-Lavergne engines. There is no fixed rule as to this size, but the relative volume of antichamber affects the characteristics of the engine, and other factors must be changed accordingly.

MR. GUERNSEY:—What mean effective pressures can be maintained with different types of injection system? I have heard it said that precombustion-chamber engines cannot deliver mean effective pressures as high as those attained with direct-injection engines.

MR. HILL:—Small Diesel engines as now made do not follow the true Diesel cycle, but a compromise between the Otto and the Diesel cycle. The ideal Diesel diagram has a flat top, indicating constant pressure during combustion. This cycle works beautifully in large engines, but it is difficult to get a small engine to operate fast enough with a flat combustion line. This modification causes higher initial pressures.

FIG. 1—INDICATOR CARD FROM 4½ X 6-IN. CUMMINS DIESEL ENGINE AT 800 R.P.M.

High Pressures Add to Weight

MR. GUERNSEY:—Light may be thrown on the question of weight by considering the relative bearing loads of gasoline engines and Diesel engines operating at a given speed. We analyzed the bearing load on a certain 8¾ x 10½-in. gasoline engine running at 950 r.p.m. According to my memory, the resultant maximum load on the bearing at this speed is 12,770 lb. If this engine were to be converted into a Diesel engine having a maximum pressure of 700 lb. per sq. in., the resultant maximum bearing load at the same speed would be increased to 25,100 lb. This seems to indicate that the Diesel engine, at least the crankshaft and the bearings, would need to be made heavier in something like that ratio. Can Mr. Hill and Mr. Cummins give figures as to the ratio between the piston area and the projected bearing area? In some Diesel engines this ratio is about 2.2:1.

MR. HILL:—The relation of the piston area to the projected area of the crankpin in Hill engines is 2.42 to 1 in the 3½ x 6-in. automotive type, 2.18 to 1 in the 5 x 7 in. and 1.8 to 1 in the 6 x 10-in. size. We do not have any bearing trouble which could be charged to overload.

MR. CUMMINS:—Cummins engines are made with piston areas about 2.31 times the projected area of the crank-pin bearing.

MR. GUERNSEY:—Is any erosion to be observed in Mr. Hill's engines because of the blow-torch action of the flame from the antichamber impinging on the piston?

MR. HILL:—Designs can be made in which such blow-torch action occurs, but we do not find that this action is as severe in our engines as in those with which we have experimented in which the injection goes directly to the space above the piston. The thickness of the piston-head and other features of the design must be made adequate to dispose of the heat.

Smooth Running Has Been Attained

MR. GUERNSEY:—I had the opportunity to ride in Mr. Cummins' car at a speed of over 70 m.p.h. The engine ran without detonation or any irregularity; and I wish to compliment Mr. Cummins on the uniform distribution of power impulses as indicated by the exhaust, which seemed to be much more even than that of some of the automobiles that are being sold.

I understand that Mr. Cummins can obtain almost any shape of combustion curve that he wishes with his engine; I should like to know what shape he prefers or can get for an engine operating at a speed of 2200 r.p.m., such as he mentions in connection with his test car.

MR. CUMMINS:—In the ideal diagram, the maximum pressure would be as low as possible, and yet as much as possible of fuel would be burned at the beginning of the injection. A compromise between these two requirements is necessary. We make our injection as rapid as we can without making the pressure too high. An indicator diagram taken from one of our smaller engines is shown in Fig. 1.

MR. GUERNSEY:—Is there not a possibility of increasing the power output of small Diesel engines by a slight amount of supercharging, without greatly increasing the weight or bearing loads? As I understand it, the amount of air is what limits the mean effective pressure. If the amount of air can be doubled, the amount of fuel can be doubled and the maximum pressure will not be very much higher.

MR. HILL:—It is possible that improvement may be made in the thermal efficiency of Diesel engines later, but we are gratified at the efficiency that has been attained now.

MR. GUERNSEY:—Light Diesel engines have been in use for several years, but no great progress has yet been made in their commercial introduction into the automotive field. What uses have been developed for such engines, and how far are they likely to be advantageous in automotive work in competition with gasoline engines?

Generating Electricity in Many Fields

MR. CUMMINS:—Uses that have been developed so far have been in fields where large amounts of fuel are used and where service requirements are rather severe. Small Diesel engines are also being used as auxiliary and standby units for larger Diesels both on land and sea. For instance, they are used during the night in town powerplants after the electrical load has become so light that the large Diesel engines do not function properly. They are also being used for pioneering in electric lighting. There is a group of small towns in Kentucky where 5 and 10 kw. sets are being used to accustom the people to the use of electricity. When

the demand is greater, other provision will be made for the current supply.

Diesel engines are being used by the Government in all the new electrified lighthouses. The authorities are aware that the Diesel engine is not yet perfect, but they believe that it has enough good features to offset its disadvantages. Many other installations are made for generating electricity in buildings. In one combination garage building, current is being generated at much lower cost than it could be bought, the building is being heated by water from the water-jacket of the engine, and the water is then used for washing cars in cold weather. In addition to that, they are utilizing oil drained from crankcases by mixing it with the fuel-oil used in the engine.

For automotive applications, the motor-truck, motor-coach and tractor fields are wide open, particularly the first two, because weight can be moved so economically by a Diesel engine. Figures by a competent authority indicate a saving of $1,300 per year for a 2½-ton truck and nearly $3,000 per year for a 5-7-ton truck from substituting a Diesel engine for a gasoline engine. These estimates were based on the minimum cost for gasoline with tax, a relatively high price for fuel-oil and the normal use of the vehicles. Operators of large fleets will wish to get Diesel engines because of the saving in fuel cost.

MR. HILL:—I think that Mr. Cummins will agree with me in admitting that neither his engine nor mine is the final word in Diesel engines. We can expect something like a finished job in automotive Diesel engines after all automotive-engine designers begin to think Diesel engines and help us to develop them. After that we will have Diesel engines in automobiles and everywhere else that gasoline engines are now used.

A. A. LYMAN

Motorcoach Operating Data Given

A. A. LYMAN[12]:—Possibly the actual operating experience of Public Service Coordinated Transport of New Jersey with a motorcoach equipped with a Diesel engine may throw a little further light on some of the questions that have been discussed. Fuel cost is one of the principal items in the operation of a large fleet of motorcoaches, and our transportation company is leaving no stone unturned to save a penny in expenses. We began trying to use low-grade fuel a long time ago. Naturally, we became interested in the Diesel engine, but we were unable to find any six-cylinder Diesel engine that seemed adaptable for a motorcoach. Finally, we selected a truck engine to try out, and this was installed in a motorcoach last September. Before installation, it was given a dynamometer test which yielded very interesting and satisfactory results.

This Diesel-engined motorcoach, which weighed about 18,000 lb. and was equipped with electric drive, was operated throughout the winter, on a fuel consumption of about 5 to 5½ miles per gal. Similar vehicles, equipped with gasoline engines, running on the same route at the same scheduled speed and with approximately the same stops, averaged about 3.3 miles per gal. of fuel. The saving in fuel cost amounts to about two-thirds or about 2 cents per mile—a saving of about $1,000 per year for a vehicle that runs 50,000 miles per year.

Fuels that we have used in the Diesel engine range from 26 to 40 deg. Baume. The fuel that we have used most is about 28 to 30 deg., with an initial boiling-point of about 400 deg. fahr., a 10-per cent point at about 460 deg., and 90-per cent point at about 700 deg.

Mr. Guernsey has asked about the exhaust gas. My tests with the Orsat outfit have shown, at full load, about 10 to 12 per cent of carbon dioxide and 6 to 9 per cent of oxygen, with no trace of carbon monoxide. Ole Singstad, superintendent and chief engineer of the Holland Tunnel Commission, knew of our experiments and was interested in the exhaust-gas analysis because of its effect in the ventilation of the Holland Tunnels in case Diesel engines should be adopted to any considerable extent. Accordingly, he had his chemists take some samples of the exhaust gas, and their figures agreed very closely with mine as to carbon dioxide and oxygen. The maximum carbon monoxide he was able to find under any condition of speed and load was 0.07 per cent.

We drove this motorcoach from New Jersey to French Lick in four days, averaging approximately 7 miles of fuel per gal. for the entire trip. You will notice that the exhaust is remarkably clean and clear, more so than that of the average motorcoach. The vehicle has been driven by a large number of operators. Many times the operator has merely been told to go and start it, and the garage foreman has merely instructed him to step on the heater switch which energizes the glow-plugs before he steps on the starter. We have never had a complaint from the public in regard to this bus. I have ridden on this motorcoach a great deal myself and have never heard any passenger make any comment upon it. We are very optimistic in our attitude toward the Diesel engine for motorcoaches.

CHAIRMAN A. J. POOLE[13]:—Another Diesel-engined vehicle was driven to French Lick from New York. It is a five-ton motor-truck having a four-cylinder engine, and it made the trip on a fuel consumption that averaged 15 miles per gal. I am sure that the people in charge of both the motor-truck and the motorcoach will be glad to give you any sort of a demonstration that you would like.

[12] M.S.A.E.—Automotive engineer, Public Service Coordinated Transport, Newark, N. J.

[13] M.S.A.E.—Manager, manufacturers' sales department, Robert Bosch Magneto Co., Long Island City, N. Y.

What about Inventions?

By W. J. Davidson[1]

Annual Meeting Paper

PROGRESSIVE business is always on the lookout for new ideas, and a certain portion of the public is dissatisfied with things as they now stand and is continually trying to improve them. Naturally, to realize a return on the time, money and brains used to develop their ideas, inventors are continually bringing their inventions to the attention of some manufacturer to produce and sell.

Approximately 6000 inventions are presented each year to the General Motors Corp.

A New Devices Committee, composed of executives, representatives of the patent department and engineers from the research laboratories and the manufacturing divisions, considers these and decides on their value.

One primary requisite for consideration by the Committee is that the owner of an idea or invention shall have obtained at least the minimum of legal protection to avoid complications later.

While the Corporation is always on the lookout for good new devices that are technically sound and can be economically produced, only a pitifully small percentage can be utilized.

Inventors should search patents to satisfy themselves that their idea is really new before going too far with their development work.

Reasons for a New Devices Committee

Every year we have presented to General Motors, through various channels, approximately 6000 inventions. Previous to the organization of the New Devices Committee, a Corporation policy dealing with inventions was difficult to formulate. As a result the inventor sometimes did not receive proper attention. To remedy this condition, the New Devices Committee was organized as a central clearing house for all inventions submitted directly to the General Motors Corp. or through any of its divisions or executives. Instead of allowing a meritorious device to drift by a devious route through various channels, the New Devices Committee steers it directly to the person most vitally concerned and does so with the minimum delay. Some of the devices are valuable, while others are not technically and economically sound, so some way must be provided to separate them so that nothing with merit will be rejected, a 100 per cent inspection that does not pass any bad nor overlook any good ideas.

This matter can be handled in many ways. This paper briefly outlines a procedure that has been developed as the result of handling thousands of devices and may aid others in the industry who are faced with the problem of what to do about inventions. No one man is competent to determine a corporation's interest in all inventions. Industry is too complex. Very often a device holds possibilities that one man might overlook. In considering several thousand devices, only a body of men, skilled in the various lines in which the Corporation is interested, can be trusted not to overlook a meritorious invention. So the New Devices Committee was formed. This Committee is composed of three vice-presidents of the Corporation, representatives of the patent department, engineers from the research laboratories and the manufacturing divisions and a suitable engineering and clerical staff. In addition the Committee has authority to call upon any of the engineering facilities of the Corporation for assistance.

The great number of inventions or ideas submitted renders it impracticable for the main Committee to consider each one, so a subcommittee has been created, consisting of a number of engineers and other employes of the Corporation to whom every such invention is submitted. The personnel of this body is such that at least one or two members thereof are fully acquainted with the subject matter of any invention submitted. The secretary of the Committee and his assistants go carefully over each invention submitted and if the data furnished by the inventor are not sufficient to give a clear understanding to the subcommittee, additional information is requested. The secretary may also, if necessary, submit the invention to someone in the organization having special knowledge of the subject matter thereof, and he may also, if he deems it necessary, ask the patent department of the Corporation for a report on its novelty; so that when it is submitted to the subcommittee that body will have all of the information and data relating to the invention which is necessary to enable it to arrive at a prompt decision as to its value to the Corporation. Certain classes of invention, such as perpetual-motion machines, are not of any interest to the Corporation, and these are acted upon by the secretary alone and are courteously declined by him.

The subcommittee has full authority to pass finally upon the merits of inventions of certain classes, but in all cases involving certain things in which the Corporation is especially interested, or where the members of the subcommittee are not unanimous in their opinion of a particular invention, the matter is referred to the New Devices Committee. The subcommittee has also the right to refer to the Committee any invention that it believes meritorious.

[1] M.S.A.E.—Executive secretary, new devices committee, General Motors Corp., Detroit.

What Is a New Device?

The Corporation is interested in receiving ideas or suggestions relating in any way to the manufacture or improvement of any of its various products; consequently the term "new devices" receives a very flexible interpretation by the Committee. Although the great majority of devices submitted to the Committee consist of articles or devices that have been patented or for which patent applications are pending or are proposed to be filed, very frequently a device, article or idea is submitted which is not capable of any patent protection.

These last-mentioned items and those upon which no patent applications have been filed cause the Committee the most concern, as frequently in a large organization some one of its employes is working upon or has already perfected a similar idea, and to persuade the person submitting such an idea that the Corporation has not attempted to appropriate it instead of giving him due credit therefor is sometimes difficult. For this reason the Committee is very loath to consider any idea or invention upon which its owner has not at least obtained the minimum of legal protection. The Committee always advises the person desiring to submit ideas that before doing so he obtain such protection. Occasionally, however, the data relating to an idea are forwarded by the inventor with his first communication.

W. J. DAVIDSON

Handling of Devices

For the last few years the Committee has been called upon to handle several hundred inventions per month. Obviously, the proper handling of such a number in a prompt, fair and courteous manner entails considerable clerical work and necessitates a highly effective office routine. The secretary of the Committee has complete charge of the organization dealing with inventions and all contacts.

A file is set up for each invention submitted and two types of file card are made out, one for the name of the person or persons submitting the device and one to classify the device itself. This furnishes an efficient means of cross-checking and facilitates the location of a file. After the inventor's letter has been promptly acknowledged, the invention is referred to engineers who have expressed interest and have made a careful study along similar lines, and their comments on the construction are requested.

Submitting a device by letter secures fully as much attention in every way as submitting a device in person. Besides, submitting a device by letter may save the inventor considerable time and money, especially if he lives a long distance from Detroit, since the Committee's activities are centered in this city. However, from 15 to 20 per cent of the devices are submitted by personal contact. In such cases the inventor contacts with the secretary or his assistants. To present the device intelligently to the Committee the secretary must have an adequate description of the invention, the necessary patent information and a commercial proposition if possible. The secretary then obtains all pertinent comments on the construction in the manner described above and adds the invention to those to be presented to the Committee at its following meeting.

The minutes of meetings of the New Devices Committee are carefully compiled and filed, since they contain the authority by which the secretary is guided in replying to the inventor. At any time in the future these minutes are available as a check on the Committee's decisions and have proved invaluable in determining the exact attitude of the Committee at that time.

Frequently, inventors ask to be present at the meetings, but through long experience we have found such a procedure a handicap to all concerned. We have a fixed rule with no exceptions. No person submitting an invention or idea is permitted to be present at any meeting of either the Committee or subcommittee.

All inventors are promptly notified of the action of the Committee, and if the invention is of no interest they are so informed. No reasons are ever given for such determination as from experience we have found that to do so is very apt to cause a more or less acrimonious discussion that serves no good purpose and only creates ill-feeling.

Should the invention be one in which the Corporation might be interested, and I might say that the proportion of such inventions is very small indeed, the inventor is contacted with. Before anything further is done an agreement is entered into with the inventor clearly setting forth the terms upon which the Corporation will undertake its investigation of the invention and the compensation it will pay the inventor in the event of its making use thereof.

Why Is the Percentage of Devices Accepted So Small?

Our experience has been that a very small percentage of the total inventions submitted can be economically manufactured and sold, some of the reasons for which are as follows: The number of inventions submitted to us in a year runs into the thousands. The percentage that we can even consider seriously is pitifully small. For the thousands of inventions that we cannot use, too often the inventor has spent months and even years, working out the most minute detail of some device that is a direct contradiction to physical laws. He may even sacrifice the comforts of life to build a model when a

paper drawing should have been sufficient to expose its inherent unsoundness. This financial and personal sacrifice on the part of the inventor is not only a matter of disappointment and punctured ambitions but is also an unjustifiable waste of money and labor.

Typically the inventor focuses his attention on some part of a mechanism with which he is dissatisfied and usually adds a part to correct what he considers a faulty design. Very rarely indeed does he subtract something or simplify a part. If his invention works, he is more than likely confident that he has therefore discovered something greatly to be desired. The fact that it works is not the only criterion of an invention's value. It must meet the demands of production and sales, and a big difference always exists between an invention working and being able to capitalize it at a profit. This failure to take into account the demands of production and sales and economics in general results again in an unjustifiable waste of money and labor on either the inventor's or his backers' part.

Frankly, as mentioned previously, business is always on the lookout for the good new devices that are technically sound and can be economically produced and sold. The manufacturer wants them as a source of profit. Why then is the percentage of devices accepted so small? The unsuccessful inventor has the habit of looking toward others for reasons when he himself is the one at fault. He is really unprepared to submit an invention as he probably has no knowledge of the previous commercial developments in the art. The inventor does not invent in his own line and too often his knowledge is limited along the line in which he tries to invent, although he may rank high in his own line of business. The majority of suggestions submitted to us come from those who have little or no experience or contact with the automotive industry. Of course some meritorious inventions are discovered by accident, but the accidental discovery is not likely to occur unless the inventor is educated and trained to observe in a particular field and is in contact every day with similar matters.

To get back to the reasons for the inventor's disappointment, he may have little idea of the requirements of the public, production or sales. Even granted that he has this essential background, perhaps he has not paid sufficient attention to the invention itself. He must be sure that it works efficiently after exhaustive tests, that he has made it as simple as he knows how and he must have established broad legal claims to the principle as well as to the construction details.

In closing, I should like to revert to the question of a corporation's attitude toward the inventors. Needless to say, it decidedly should not be inimical. We are both striving toward the same goal, the perfection of the automobile. The inventor may have a good idea; many good ideas do emanate from outside. We must be cognizant of this fact and welcome the opportunity of examining all ideas with the view of ultimately purchasing them, provided they fulfill the requirements.

To be forewarned is to be forearmed, and the inventor approaching industry had best realize that he is dealing with trained engineers and leaders in commerce, who have every facility for test, research and development and whose ability has built one of the largest industries ever known. This fact should cause the inventor who is unprepared and impulsive to pause and consider but should encourage the inventor who is prepared and who has built on a sound foundation.

THE DISCUSSION

GEORGE L. MCCAIN[2]:—In preparing a discussion on this subject, I have purposely outlined a few problems relating to inventions and inventors, entirely independently of the paper presented by Mr. Davidson. I do not care to take issue with him on anything he has presented but rather to bring out from our own angle some conditions that we believe may result in a better understanding by inventors of the point of view of the manufacturer of automobiles or automotive equipment.

To begin with, inventors can be divided into a number of different classifications, just as automotive engineers can be classified. Some engineeers still take it as a personal insult to be told that they are wrong. Others are just naturally obstinate in maintaining their ideas on certain subjects and, while they are not positively insulted when told of their mistakes, they uphold their opinions until their position becomes unbearable. Still other engineers have the right theory relative to certain devices but maintain this theory at the expense of manufacturing, with the result that their work cannot be commercialized with resultant benefit to the company employing them. The vast majority of engineers today, however, are broad-minded and willing to compromise with manufacturing methods and with public opinion as expressed in desire by the public for a certain kind of product. We are assuming that the last kind of engineer is the one who has to deal with the various kinds of inventor, who will now be described.

First, we have the patent attorney who might also be a promoter for his own idea or for that of a friend or client who may not be able or who prefers not to submit his own ideas. Next, we have the professional inventor who usually has a holding company or syndicate and who has from one to four or five different things to present at the same time. Then, we have engineers in other lines than the automotive industry or professional men who, knowing something of engineering in general, conceive of ways for improving the automobile as one of their tools. Next, we have to deal with mechanics who have no knowledge at all of the fundamentals or of the physics involved or of the previous art of invention. Contrasted to these, we have the college graduate who knows his fundamentals, physics and kindred subjects but who has only very vague ideas as to the mechanical limitations of certain devices. Lastly, we have free thinkers who sometimes are very radical, who grope wildly for new ideas, who never investigate and who often do not even apply for a patent on their idea. Many other types of inventor are difficult to classify but nevertheless sometimes send in good ideas that prove to be practical. All inventors cannot be dealt with in the same standardized way, and some inventions submitted require many days of investigation and others

[2] M.S.A.E.—Research engineer, Chrysler Corp., Detroit.

only a few minutes to determine the real merits of the new device.

Some Problems Met in Investigating Inventions

The relation between the inventor and the automotive engineer who acts for his company in gathering complete data relative to new ideas, in maintaining goodwill and in courteously explaining to the inventor why certain things cannot be incorporated into motor-cars to meet the ideas of the inventor has many angles. Trying to define the proper methods of dealing with the various kinds of inventor, which have been classified above, would be difficult. The policy of our company is that of encouragement for the inventor with any new idea and, in maintaining this policy and in trying to maintain the good-will of the inventor, we sometimes must take considerable time in investigating the new device submitted or in discussing the new theory advanced on paper. Very often we learn something that we would not have known if we had been inclined to reject the invention on the basis of its general characteristics without a thorough analysis. Sometimes a careful discussion of a new device, with the inventor, will bring out various details and factors concerning the use of the device, with the result that the inventor does not feel inclined to urge the adoption of his device further. In other words, a careful consideration of his proposal has resulted in his being convinced of the unsoundness of his theory, and he obtains his answer without any formal action on our part. On the contrary the same frank discussion often discloses something of interest and value to us.

Everyone knows of the mysterious type of inventor who has a certain model in some other city to demonstrate and nothing will do but have a representative of the company go to witness a demonstration and to meet the promoter of the scheme. Perhaps these methods are ideal for the promoter who sells stock in his new scheme in this manner, but in most cases such investigations are a waste of time on the part of the engineer who investigates from the standpoint of the facts involved. In fact, very few demonstrations are of any value in the consideration of a new device. Usually, if a device has real merit, a description or photograph with whatever data are necessary to describe its function will help the engineer to form a fair and correct decision more than a demonstration. We believe that the real value of a demonstration is to illustrate the working of a theory that has already been explained with a careful analysis of the fundamentals involved.

One of the hardest problems is to talk to a practical mechanic, who perhaps has been working on automobiles, has no knowledge of physics or the fundamental science of mechanics and has no access to previous records, so that he can find out previous failures in the line of invention in which he is interested. Very often, the mechanic is so close to his own work that he lets his imagination run wild on new devices more or less foreign to his own experience. Sometimes, this class of inventor has spent good money in making up models and, because of his undoubted ability, is not inclined to take suggestions from others who appear to be less of a practical mechanic than he. In such cases, an argument is sure to result and this presents one of the most difficult cases as the variation in the point of view of the two men involved is so wide. In this class we have the convict who invents locks to prevent the theft of automobiles. We have also men who can make models of various devices to accomplish perpetual motion, and nothing will convince them that such a machine is impossible.

We have many inventors write to us explaining their new devices and, in addition to wanting to sell us the invention, they do their best to get us to employ them to work out the inventions, which we very often cannot even consider seriously. However, any consideration must be based on the facts in the case and all of the facts must be brought out to make a satisfactory arrangement for the inventor, the engineer and the Corporation.

Finally, the automobile of today is a tremendous compromise. Public demand, competition and style dictate engineering policy. Revolutionary inventions have been incorporated into automobiles in advance of public acceptance of the principles involved and have failed, only to reappear again when the public, or related conditions, were ready for them. Public demand cannot be defined as a desire for a definite thing, but merchandizers of automobiles should and do know what the public will accept and that must be what we call public demand. We know of many principles that could be applied in devices for the automobile, most of which would please a few automobile owners and which would positively help sell, regardless of cost, whatever car applied such a device, but which might be useless or unnecessary to the large majority of car users, whom we must call our public. Therefore, we must say to inventors that we are not interested, sometimes, when the device presented is workable and practical.

Inventors often ask: What can we work on, what can we submit that you *do* want? Many things are desirable, and I cannot attempt to name them here, but we have suggested to those who ask this question some things, such as "Show us how to increase the thermal efficiency of the present gas engine," or "Show us a cooling fluid that is cheap, that has a high boiling-point and that will not corrode metal or rubber," or "How can we save some of the waste power that now goes through the exhaust?" We want many problems solved, but economies must be considered in the solution of each.

Chrysler Procedure Similar to General Motors

Mr. Davidson's definition of a new device meets our idea of it perfectly. Our committee set-up is rather similar to that of the General Motors committee; most of its members are engineers and we do not call on all of them at the same time. If, for instance, the invention relates to a carbureter, we do not call in any body engineers. We attempt to call on a certain group that is interested in that particular device and we have so many devices submitted that we can often have three or four men considering some in each subcommittee. When a new device is submitted, without any protection but simply mentioned in a letter, to satisfy the inventor and to take no more of our own time than necessary, we suggest that he get the letter in which he explains his idea notarized so that the date can be established legally if necessary. This seems to satisfy most of them, but I will say that invariably the ideas which are submitted that way are very seldom new. Another class of inventors is rather a problem, at least the method that they use makes them a problem. They know somebody in the sales department and have some-

thing on the car that is different and appeals to a certain few. When the sales executive or sales manager drives a car and it has something new on it, the novelty of it immediately appeals to him and he expresses his desire for it. That does not help us very much as we still have to analyze the whole device, find the faults and limitations of such a device and then usually have to explain to the sales department why we do not want such a device. Sometimes we find we are wrong.

GEORGE L. MCCAIN

We have another problem, the small stockholder who thinks that because he owns a few shares of stock in the company he is privileged to send in ideas to improve the car. Perhaps he has been driving cars for many years and has certain ideas. Usually, these come in addressed to the head of the company. Naturally, we get the letters and if our reply is unfavorable to him, he again writes to the head of the company so that it makes considerable unnecessary correspondence. Still, it is a problem that we do not know how to deal with in any other way. We cannot take care of it in the routine manner. I believe that everyone else must have about the same problem.

The letters that we send out to inventors are not form letters. They are worded similarly but each one is made to suit the conditions involved. As Mr. Davidson says, we never give the reasons why we reject certain inventions. We invite the inventor to come in if he wishes to and we are always willing to tell him why certain inventions cannot be used.

W. J. DAVIDSON:—Our practice regarding letters is the same as that mentioned by Mr. McCain. We never write a form letter and we have no mimeographed letters. Our letters are all individually typed.

I forgot to mention one very important point; we will test a device. Assuming that we may want to build and test such a device, we invariably make an agreement with the inventor before proceeding, which sets forth the royalties to be paid and whatnot. We do not make any tests before making such an agreement that covers the situation wholly and completely from our standpoint. This eliminates any trouble that might arise afterward.

RALPH H. UPSON[3]:—What is your policy with regard to patents in such a case? Do you encourage the inventor, if he has not already patented his device, to go ahead and patent it or do you make your experiments first?

MR. DAVIDSON:—So far as I can recall, we have never run tests or wished to run tests on a device that is unprotected. A man who is experienced enough to have a device that you can be interested in usually has obtained some form of strong, let us say legal, protection.

WALTER T. FISHLEIGH[4]:—I am impressed with the fact that the method outlined, although varying in details with different companies, is aimed to accomplish the same results, to be fair, first to the inventor and, second, to the company. I know that in very many cases the inventor seemed to feel that he was not being treated fairly. In so many sad cases he did not realize that the treatment he received might be the very best thing in the world for him.

That the Ford Motor Co. gets something more than 6000 suggestions per year, I suppose is perfectly natural, as the inventor figures that his device is worth about $1 per car and a daily output of 8000 cars will give him a good compensation if he can interest us. Our organization is not as rigid in the matter of committee organization as General Motors, but the functions are practically the same in that suggestions come ultimately through the management or the engineering department to certain individuals as a subcommittee and these subcommittees have authority to act immediately on such ideas as perpetual motion and others that I believe are even worse. If the idea possesses some merit, it is passed on to a rather large committee. A number of humorous sides make this policy worthwhile. It is rather distressing, sometimes, but I like to think of the good side rather than of the bad.

Some of the Suggestions Made

About seven years ago, before locks were used on the closed cars of any reasonable price, one inventor from Buffalo sent in the suggestion that we put them on the Ford cars. Our reply was that we were not interested. We had a valid reason for not being interested then. In the first place, door locks cost about as much as the front half of a Ford engine at that time. Also a number of complications entered into it. About five years later door locks came down within the realm of automotive production and we put locks on the Ford closed cars. Then the inventor stepped forth with his attorney and threatened suit. We had an awful time because his invention had been incorporated in the closed cars. His invention, of course, was a suggestion of why we did not put locks on our closed cars the way Pierce-Arrow had been doing it for a number of years. That, of course, changed my idea of what was an invention and what was merely a suggestion.

W. T. FISHLEIGH

The question has a sad side that this care with our system and the method of handling these things will help out. I never talk about inventions, or think about them, that I do not think of one fellow in whom I took some interest and with whom I spent considerable time. He was a fine, upstanding fellow and told me the whole story. I have no doubt that it was so. It extended over a considerable time and I had a chance to check up on some of it. He had developed a farm with his wife and had saved up a certain amount of money. Then he got an idea on a wheel and had spent every cent in its development, being encouraged to a certain extent by friends and certain men in his State. Then,

[3] M.S.A.E.—Aeronautical engineer, Red Bank, N. J.
[4] M.S.A.E.—Engineer, Ford Motor Co., Detroit.

leaving his wife to get rid of the farm, he borrowed money to come to Detroit and market this wheel. He told me that he had been to a number of places and our decision was the same as that of the others, that there was absolutely nothing in the idea of the wheel. Those things, I know, justify our spending a little time trying to handle them in a fair way. I agree entirely with the other speakers that wherever we can we should keep the man from selling his farm, putting his whole fortune into something and borrowing money to come here and find out what he could have learned for a 2-cent stamp.

MILTON TIBBETTS[5]:—This matter of dealing with these inventors in this way, as expressed here, is certainly the only one. We cannot enter into discussion with them; it would be endless if we did. We must be firm in rejecting inventions for lack of interest; otherwise inventors would be encouraged and would continue to spend money and mortgage their farms.

MR. DAVIDSON:—Two years ago we prepared a pamphlet entitled, The New Devices Committee of General Motors, which tells in considerable detail how to submit a device to General Motors to have it receive prompt, careful and courteous consideration. This pamphlet has enjoyed tremendous circulation and has been well received by all sorts of people. It is very useful to banks and that class of people because they continually are requested through various channels to give inventors letters of introduction to General Motors Corp. The pamphlet gives complete information how the contact should be made and it has been a great comfort to our friends on the outside.

When we get a letter that says, "I have a wonderful idea. Who is the proper person to submit it to?", all we have to do is send the pamphlet. Uusually the inquirer is very much pleased; writes to thank us and then sends in his idea.

Patent Searches Would Save Time and Trouble

S. M. UDALE[6]:—One point that I think might have been made is that sometimes we can escape from an awkward situation by directing the inventor to make a patent search. I would like to point out that the searches made in the City of Washington are not as satisfactory as they would be if the patents were classified not only by the claims but also by the disclosure. This would mean spending considerable money in the Patent Office but I think the Patent Office should spend that money and it would be for the benefit of all of us, if the searches would be more reliable. The foreign patents generally are better classified, especially the German ones and the countries following the German classification. If I am in a hurry and have not the time to make a complete search, I frequently get data quicker on the foreign patents than on the American ones, which is not to the credit of the United States Patent Office.

An inventor had very powerful friends, an ex-Prime Minister of England among others. Through this man he obtained the services of the *Daily Mail*. That paper published a column attacking the department I belonged to and myself as mandarins because we would not consider his device which enabled airplanes to operate on kerosene and thereby avoid the fatalities from burning. This inventor had submitted no invention before the attack. He made the attack first and then he followed it up by an interview. I was delighted in the interview to show that a gentleman in the General Electric Co. had already made that same invention. He learned this to his astonishment and I had no more trouble with him. The invention had no merit.

Inventions in the Aeronautic Field

MR. UPSON:—Until I heard some of these experiences from the automobile field I had always supposed that aeronautics was the great field for crank inventors. One of the interesting things is the perennial invention that seems to crop up every so often, exactly the same thing all over again, certain types you just expect to see reinvented every little while. Of course, they are always the impractical kind. If they were anything other than the device in question, they would long since have been worked out with so many people apparently working on them.

The psychology of the thing is possibly one angle that might be given more attention in an effort to discourage the crank inventor. Without having had the time to put much effort myself in this direction, it has rather appealed to me that the crank inventor is primarily a state of mind. An invention may be impractical but if the inventor maintain the proper perspective on it and a business-like attitude, he would not be called a crank inventor. He seems to be the kind who has been steeped so long in the fumes arising from a single idea that it is just a part of him. The conviction that he has a wonderful invention is to him as real as his own existence upon earth. When he reaches that state, apparently not much can be done to disabuse him of the idea. If he can be caught soon enough, however, before he has put all that concentrated attention on it, then I have a feeling that considerably more can be done. The effort ought principally to be directed against that loss of perspective, or to put it more positively, against giving overmuch attention to some one idea before trying to interest somebody who is a real authority on that subject.

MR. MCCAIN:—Mr. Upson's remarks bring up one thing that I meant to mention, the inventor who submits something in a line entirely foreign to the ones in which we are interested. For instance, at present we are not interested in airplanes, but often we have airplane engines or airplanes themselves submitted to us. We are not exactly certain as to what is the proper method of handling those. We might very often refer them to companies more interested in a general way.

MR. DAVIDSON:—Since we have entered the aviation field, we have established a committee somewhat along the lines of our own and all inventions we receive on behalf of General Motors are sent to it. Anything that we are remotely interested in or have operations dealing with, we send to the proper place.

DR. PAUL M. SCHWEITZER[7]:—During the war I served in the Austro-Hungarian army. That was an organization larger than Chrysler Motors, perhaps almost as large as the General Motors, employing about 4,000 000 or 5,000,000 men, even if it did not pay wages as high as the Ford Company. It was a big business and we had a Committee on Inventions. We received inventions at a rate exceeding 6000 per year. Some of the inventors wanted to help themselves at the same time;

[5] M.S.A.E.—Patent counsel, Packard Motor Car Co., Detroit.
[6] Patent attorney, Holley Carburetor Co., Detroit.
[7] M.S.A.E.—Associate professor of engineering research, Pennsylvania State College, State College, Pa.

some of them were entirely unselfish and wanted to help us win the war. I was not on the Committee of Inventions, but a friend of mine was. I asked him how he handled the inventions that came to his hands. He replied that he turned them down indiscriminately, because in that way he took less responsibility on his shoulders than if he submitted an invention farther. I wonder if the invention committees of these corporations, consisting of paid employes, do not feel the same way; and if not, why not.

The Government's Attitude on Inventions

E. P. WARNER[8]:—The Government's handling of aircraft inventions may contain some points of possible industrial interest. It certainly contains some points of interest, but I am not sure that practical use can be made of them.

For a long time the conventional course of an inventor in the City of Washington has been recognized as being Army, to Navy, to Department of Commerce, to Army, to Navy, and so forth almost indefinitely. Some of them have been down there for about 9 years with one idea. I suspect that the same thing happens in the automobile industry, that enormous duplication of effort exists.

EDWARD P. WARNER

As for the condition of affairs in the army of the Austro-Hungarian Monarchy, that, I presume, is rather difficult to avoid in time of war. I do not think it has been paralleled in the attitude of this Government toward aeronautical invention, which happens to be the type that is perhaps most prolifically offered in time of peace when the pressure of immediate emergency is less and we have more leisure in which to consider new ideas. I digress to make that remark because it leads to the statement that however sympathetically we start out to examine inventions we almost inevitably acquire, as a good many of you know from experience, an extremely cynical attitude after a few months.

As I indicated, the Army and Navy, and later the Department of Commerce and the National Advisory Committee for Aeronautics and the Weather Bureau and other organizations, realized that a redundancy of effort due to talking to the same inventor existed. One of the things that the Morrow Board recommended in 1925 was that all this should be coordinated under the National Advisory Committee, and there was passed, as a part of the Army's five-year bill, in the summer of 1926, a section of that statute which provided for the creation of a Board on Patents and Designs, consisting of the three Assistant Secretaries for Aeronautics, War, Navy and Commerce, to receive all ideas on inventions and all designs for aircraft or parts thereof submitted to the Government, get a report from the National Advisory Committee and buy for the Government anything, whether patented or unpatented, that appeared desirable or useful at a price not to exceed $75,000. They were given a wide scope of authority to purchase directly designs having no legal standing as property. In the first year and a half approximately 700 inventions were received and reported on by the National Advisory Committee for Aeronautics, and about three of those received a tentatively favorable preliminary report. They contained some degree of hope. About 97 per cent of the rest could be thrown out at a glance. The essential things learned were as follows: An enormous amount of energy is wasted in invention, but no way of stopping it seems possible. By the time a man has reached the point of formulating the idea, he is irremediable, and if we tell him we cannot use it, then he says that we are no good, that we are experts and all experts are prejudiced or that we are in the pay of the enemy or the trust or something of that sort. We might as well let him go his way and only hope he will stay a long way off.

Unfortunately, as I say, in the City of Washington they stick around indefinitely with the same idea. We had correspondence for years with one fellow, reams and reams of paper covered with mathematics. He had a scheme for storing a flask of helium in an airplane and having a balloon packed on the upper wing so that when the machine went into a nose dive the helium could be used to inflate the balloon and thus the ship could be straightened out. We gave him scientific explanations of the impracticability of that, which he did not understand because it was too complicated, and then when we gave him a simple explanation he came back at us because he did not understand that either. He did that repeatedly. Finally, the correspondence boiled down to a sort of "Katie did" and "Katie didn't" affair and he came back to us repeatedly with the remark that it was very apparent to him that we did not want airplanes to be safe and that he thought we were unfit to hold our jobs. Any number were just like that. We cannot do anything about it as far as anybody has been able to discover. They go their way and waste considerable time and some get to be very pitiable cases, just keeping body and soul together. Anything that can be done to avoid duplication in handling is very desirable. In the case of the Government this coordination has been an admirable thing.

I do not know how the New Devices Committee works, but a certain turnover in the inventions personnel is necessary, so to speak, if inventors are to receive sympathetic consideration. To have inventions examined as a side line by a number of people who are doing other things as well is often wiser. Carefully picked people are what we need, if we wish to make sure that the one grain of wheat in the barnyard full of chaff does not get through. While I think that the Advisory Committee has had admirable success in preserving fairness of judgment and sympathetic judgment toward everything coming along, looking at 5000 or 6000 ideas without getting to the point of taking up each one with the determination of finding out what is wrong with it as quickly as possible is extraordinarily difficult. We know that in 99.9 per cent of the cases more or less, but not much less, something will be obviously fallacious about it and it will be evident that the inventor did not understand the mechanics of the problem at all. The Government has, of course, entirely escaped the commercial phase. On the other hand, probably the Government gets a little more than its due share of pure

[8] M.S.A.E.—Editor, *Aviation*, New York City.

nuts. The figures that I have given are undoubtedly somewhat unfair to the average percentage of merit in the inventions that are submitted in industry.

The people who have no idea how industry is organized or what can be done with an invention after it is disposed of, who have no idea how a company operates to exploit an invention, commonly send it to the Government first. The Government is far away and they think of it as having all the money in the world. A common form of letter, usually written with pencil on cheap stationery, is one that gets about a third of the way through a crude explanation and then says, "Can you send me the $75,000 now, or do you need more facts?" They want to sell it outright, and the Government is then supposedly the easiest mark for that sort of trade.

CHAIRMAN JOHN A. C. WARNER[9]:—How do the Navy Department and the Advisory Committee handle the situation when an employe makes an invention? Is that turned over exclusively to the Government, or is the employe given an opportunity to exploit it privately, or how?

How Government Departments Handle Inventions

MR. WARNER:—In answering that I will say a word about how inventions in general are handled by the several departments. We will suppose that a scheme comes to the Navy Department, either addressed to the Secretary of the Navy or to the Bureau of Aeronautics. If it comes from somebody with whom the Bureau of Aeronautics has had some dealings or if it is along a line of development upon which it is already working, it may take it up directly. If, however, it is in the nature of pure invention, starting from scratch and has no apparent application to a piece of work that is already under naval auspices, it is sent to the National Advisory Committee, which is asked to report on it. In the case of a favorable report the Patents and Designs Board, composed of the three Assistant Secretaries, has the opportunity to decide whether it will be purchased for the Government and, if so, how much will be offered to the inventor for the design.

As to the question of the specific case of an invention by a Government employe, I cannot quote the law on that in detail. However, it contains nothing that prevents the making of compensation to a Government employe for work that he has done outside of the immediate channels of his employment or even within those channels, although the nature of his employment or regular work is taken into account. A civilian mechanic in one of the Government departments developed a very marked improvement in ordnance some years ago. It was, in a sense, in the line of his employment, but it showed ingenuity and initiative beyond what was anticipated when he was hired for the particular job that he held. He was given a fairly substantial sum of money, as Government awarding goes. In that case a special appropriation had to be made by Congress, as no sum was available for that purpose. However, his recognition was for exceptional work largely done during the regular hours of employment at a daily wage.

A second case is that of an enlisted man in a Naval Air Squadron, who developed an improvement in a certain piece of aeronautic equipment, again in the line of his employment as far as an enlisted mechanic can be said to have a single line of employment. He, also, was given compensation. He took out a patent on his device and I think will make, shortly, some effort to exploit it commercially without any interference whatever from the Navy Department. The Government never, in any case, claims any commercial right over the invention.

The third case is that of an officer who carried on, partially at his own expense, certain experiments on flight-testing equipment. In that case his full right was conceded and the Service, although using his first equipment without paying him royalties, considered the question of compensation for the right to manufacture, or have manufactured outside, in quantity very much as it would have if he had been a civilian. On the whole the Government is liberal in that matter and in some cases more so than might be reasonably expected of any commercial employer.

CHAIRMAN WARNER:—Do you recall, Mr. Udale, how the British Government handles the same phase of the work?

MR. UDALE:—I do know that when the war was over an inventions award committee made awards to a large number of inventors. I happened to receive one of the awards myself and that is how I recall the facts.

MR. WARNER:—I have spoken very highly of the Government's liberality in dealing with inventors within the Government service. As some of you know from experience, the present state of the patent law as it applies to dealings with the Government and the individual is unsatisfactory in the highest degree. That has nothing to do with the General Motors Corp. or any corporation as a purchaser of patents or inventions, but I feel very strongly on it and take this opportunity of expressing my views.

Almost invariably the rule is that some degree of anticipation of an invention can be suggested, which might not be sustained in court, but something can always be suggested by a lawyer on practically any patent that comes along. A patent that is submitted to a Government department for adjudication of legal authority as to validity almost invariably will receive an unfavorable report, whereupon the administrative men take the report and say the scheme is interesting, but that they have no authority to pay anything because it appears that the patent is of questionable validity and nothing can be done unless it goes through the Court of Claims, which, as you know, is a tedious business. The Government is much slower than a corporate purchaser and is almost compelled to be under present conditions. Certainly, this Government is much slower and much more hampered in its negotiations than other Governments because it is bound by absolute, strict legalism and can pay only where the validity of the patent appears unquestioned and a legal right in the invention exists.

The greatest step ever taken by any government in dealing with the inventor and in encouraging invention was taken by the British Government when it formed the board of awards for inventors. That was a post-war measure, but it is something that every government might keep up indefinitely if legislative authorities would trust the executives for once and provide for an award made in equity for the value of the contribution rather than for the legal value of the patent that the inventor has thought of securing on the contribution.

MR. UDALE:—Apparently no attention was paid to

[9] M.S.A.E.—Assistant research engineer, Studebaker Corp., South Bend, Ind.

whether or not a patent had been obtained. The question was purely one of equity. Some of the inventors were not satisfied and went to the court. I recall one case where a very eloquent attorney convinced the court that his client had won the war and he received a very handsome award for his meritorious invention.

Checking Patents

GEORGE B. INGERSOLL[10]:—This discussion is particularly interesting to me, being a patent attorney and also an inventor myself. I have heard of the liberality of the Government and I am rather inclined to believe that it would be liberal relative to awards on patents. It is very liberal in many instances relative to the inventor's and the attorney's time regarding the getting out of a patent.

What practical procedure is involved in the final check on a Government decision regarding a patent? The longer I am in this business the less inclined I feel to pass judgment upon an inventor's idea, for, many times, where I would discard the first plan he shows me, I do not know nearly as much about it as I thought. Often unqualified approval has been given on some idea and only later I find that it does not have very much of a basis for a real idea.

MR. WARNER:—That depends on the nature of the device. The attempt has always been and should be made to be very sympathetic, to look for points of merit. That is true for the aeronautic inventions submitted to the Government and I can say the same on the submarine inventions that followed the disasters to the S-4 and S-51. In the case of aeronautics the percentage is 95, and just about the same for submarines, where the ideas are obviously absurd and where the inventors show that they have no knowledge of the fundamentals. In fact, I think that 60 per cent of the aeronautic inventions fall in one of a few classes of long-established fallacies. The vacuum balloon, for example, comes up over and over again in various disguises.

The check on the accuracy of an invention depends entirely on the apparent merit, on whether or not the inventor knows what he is talking about and how close a case it is. If the National Advisory Committee for Aeronautics was in any doubt, I am sure the people who examine the inventions would call up acquaintances in the War and Navy Departments and ask their opinion on certain points at issue, and if they are enough in doubt to give a tentative report, that would be circulated to the technical section of the Departments interested to get their verdict. Any invention that shows the slightest degree of hope is examined independently in at least three offices before being rejected.

MR. INGERSOLL:—I thought that in many instances an idea may pass three or four bureau checks and in the last analysis a practical deduction would show it to be a fallacy in design.

MR. WARNER:—That is not so likely. So many ideas fail of attainment on the theoretical checks that the other case hardly ever arises. Where it does, of course, if the idea appeared in theory to have merit it would be turned over to the Department most interested to develop. They would try the idea out in practice to see whether or not it worked to such an extent as to encourage further expenditure of money on development or research. The Government would not, ordinarily, buy anything except a pure mechanism on which final judgment could be passed on theory alone without having practice.

MR. INGERSOLL:—A great majority can be discarded by almost a superficial examination.

K. J. DE JUHASZ[11]:—We heard about the humorous side of inventors and inventions this morning. Surely many of them have an element of humor, but most of them do not lack grim drama either and even tragedy.

Edison is credited with the saying that an invention consists of 1 per cent of inspiration and 99 of perspiration. On my limited experience as an inventor I may venture to analyze this 99 per cent. Nine per cent of it is drawn by wrestling with Nature's obstacles, by overcoming the technical difficulties. This part of the struggle is interesting and exhilarating. Nature does not yield easily, but she is a fair opponent. The remaining 90 is caused by the struggle in moving the human inertia. This is the grimmest part of the battle; the putting the invention across, introducing it into use, in the face of opposition, disbelief, hostility, greed. This is the part of the fight in which the inventor has to stake money, health and future, if he is to be successful. For this struggle the inventor is usually ill-fitted. The very qualities which make him an inventor militate against his having business ability. Thus very often others reap the harvest of his labors.

I think that the authors and composers, who are comparable with inventors as regards the creative nature of their work and also their temperament, have less difficulty in securing a just reward for their labors. The copyright costs less effort and money and seems to give a more effective protection than a patent does. Perhaps some sort of an Inventors' League, on lines similar to the Authors' League, could bring the inventors' problem nearer to solution by legal advice and standardized contract rules.

SIDNEY R. DRESSER[12]:—How does the New Devices Committee cover, if it does, the inventions that are filed by people who never come in? Does it keep track of applications for patents on inventions filed at the City of Washington and not actually submitted to the Corporation?

One other point that impressed me is the very pleasant change in the attitude toward inventions which now seems to be one of absolute fairness where merit is due. I think that this is a very pleasant attitude to note all the way through.

OLIVER E. BARTHEL[13]:—I take exception to the last speaker's remarks. Some of the 26 or 28 patents that I secured and one in particular is being infringed on by 43 makers of automobiles at the present time. If there is any fairness in the way they treat the inventor these days, I have not been able to find it.

CHARLES P. GRIMES[14]:—Many honest and sincere workers desire counsel on ideas that may have merit without the slightest chance of ever obtaining it. Costly contacts with patent attorneys who will gladly patent a seven-sided nut or something entirely foreign to the idea at hand have absolutely precluded reliable council or protection to the inventor.

We have just learned that large engineering corpora-

[10] Chief engineer, Federal Motor Truck Co., Detroit.
[11] Assistant professor of engineering research, Pennsylvania State College, State College, Pa.
[12] M.S.A.E.—Executive engineer, Kent Garage Companies, New York City.
[13] M.S.A.E.—Consulting mechanical engineer, Detroit.
[14] M.S.A.E.—Grimes Brake Engineering Service, Syracuse, N. Y.

tions protect themselves from inventors by a committee that refuses to speak with any inventor until he has first been properly trimmed by a skilled attorney for a so-called patent, a pretty piece of paper full of trick words and phrases seldom understood by the patent examiner or the man who wrote it, but always legal tender for a first-class lawsuit. Many attorneys accept from $100 to $800 for a wonderful search and a like amount for obtaining the wonderful patent which they probably knew to be junk before they started work on it. I appeal to anyone who can provide honest counsel and a few words of practical advice to wash the nonsense from the inventor's mind, to keep the mortgage off the farm and save the inventor from wasting his time in the attic or cellar upon ideas that are already stale or unneeded in our commercial world.

Many years of research work with a patent or two have placed my name on the sucker list at the City of Washington. I get plenty of mail telling me about my wonderful patent, which I know is junk, and asking for my money in various ways to exploit my patent and my vanity. I feel that something should be done to protect the inventor against this misrepresentation through the mails.

I presume that the patent examiner has a perfect right to feel content with his work the same as a coal passer with the idea that he is doing the best he knows how. We call them both dumb at times, but I think I get the most fun from reading a long letter from an examiner telling why a device will not work as I sit watching the model perform very nicely. At this very moment I have been so unfortunate as to contact with an examiner who refuses to concede that the flow of watery fluids may be expressed by $V = \sqrt{(2gh)}$ and is now asking for a demonstration of this relation.

I should like to have someone comment on a way to protect the honest and sincere person with ideas who cannot spend $300 or $400 for patent trim and put him in contact with men who know and can set him straight at once. I have little worry for the safety of the Patent Committee just now because its superior numbers should be ample protection at all times.

MR. TIBBETTS:—A bill is before Congress at present which most of the manufacturers, particularly in the Manufacturers' Association, and most of the good patent attorneys, have been trying to get through Congress for a number of years. The purpose of it is to give the Commissioner of Patents more authority over the patent attorneys. That will assist, to some extent, in getting rid of the attorneys referred to by Mr. Grimes who do hound the patentees. The Commissioner, so far, has not had the authority that he would like to have in stopping these attorneys. That bill may or may not get through Congress. We hope it will.

MR. DAVIDSON:—I am afraid that Mr. Grimes might have misunderstood me when I spoke. We never recommend to a man that he apply for a patent. We tell him to get protection, not for ourselves; we want him to be protected. That is the reason we will not listen to inventors with no protection.

Another even more important reason why we will not listen is this. If you undertake a cooperative development program with an inventor, I will guarantee that you will have a disagreement at the end of the time as to who supplied this and who supplied that. In other words, you can never arrive at the equities in the situation as to what you get and what you do not get.

We do not want that situation to arise, so we tell him to get an equity and sell it to us. Our attitude is always that of protecting the inventor. We lean over backward to protect him and his equity to give him a just reward for anything that he contributes. That is the attitude of the General Motors Corp.

MR. UDALE:—I would like to emphasize what I said about reclassifying the patents in the City of Washington. If they were reclassified, the cost of these searches would be cut in half at least. In the Public Library in Detroit we have a British patents classification, but no American one. The set of American patents in the library is not accessible to the public; they do not know how to search them, nor does anyone. A partial search has been made by a local attorney, but that is difficult to handle. The situation is that this Society should urge the Department of Commerce to reclassify those patents from an engineering and not from a legal point of view so that all similar inventions should be classified together regardless of what they claim.

L. F. BURGER[15]:—Is the patentee also protected by the patent officials in the City of Washington? I am satisfied, owing to some experience I have had in the past, that they are not altogether as fair as they might be. If a patent application that is a little hard to understand comes to them, it is usually thrown back on the patent attorney for further explanation, who then must go over the patent application again and write out a very clear and simple explanation. Sometimes the patent attorney would be a little stubborn and finally decide that the examiner is right.

Some years ago I applied for a patent on a double-acting, two-cycle, single-cylinder engine and hired a patent attorney in Cincinnati to make the application. The patent was rather complicated and took considerable thought. In other words, to comprehend the different movements and functions of the device, it was necessary to be in a study where one would be undisturbed. Rather than do this, the examiner rejected the application on the ground that there was infringement; a British patent issued to a Mr. Singleton was cited. I was disappointed to think that my device was not new and told my patent attorney to get a copy of the Singleton patent and see what he had. When we got the copy, we found a difference in the Singleton patent and my application that was as great as the difference between day and night. I ordered my patent attorney to get right back at the examiner and impress upon him that it is his duty to give all applications due consideration and grant patents to such applicants as may have a new device. This was done and in a short time, not more than three or four weeks, the patent was granted as originally applied for with an apology.

M. R. WOLFARD[16]:—As long as the question of patent procedure is up, I think we all find considerable delay in getting effective action on the merits of a patent application, especially if it is something that has been worked on for a number of years. I have had this experience over and over again, the patent application came back about three times before it received real consideration. The idea had actual merit and in every case we secured almost full value of the claims as originally drawn. A claim might have to be reworded to

(*Concluded on p.* 359)

[15] M.S.A.E.—Chief engineer, International Harvester Co., Chicago.

[16] M.S.A.E.—Engineer in charge of research, Hopewell Bros., Watertown, Mass.

Powerplant Economics

Discussion of Alex Taub's Semi-Annual Meeting Paper[1]

SOME discussers agree and others disagree with the author. The Chairman points out that design limitations render impossible the combining of all characteristics in an engine, that engineers must learn to face and be guided by facts, however distasteful, and that they should be vitally interested in the economic phase of the industry. Another discusser remarks that purchasers in the different price classes may not desire the same characteristics or result per dollar. Through improvements and refinements engine weight per horsepower has been reduced, and light high-speed engines permit the use of lighter chassis parts, resulting in a less expensive automobile. Engineers are seeking to "make a pound of material work harder," and mass production has made it possible to sell it cheaper.

Together with other features of European design that American engineers copied between 1910 and 1914 is the small-bore and long-stroke ratio in the high-speed engine, which, with high-compression, results in high temperatures. These have forced the metallurgists and fuel and oil engineers to assume a large part of the engine-designer's burden of overcoming the consequent difficulties.

Neither high-speed nor low-speed engines need suffer any longer from mixture-distribution troubles, asserts one discusser, since a new development based on a principle that supplies a dry mixture renders distribution independent of velocity in the manifold.

Close checking of the operation of several fleets of cars in the lowest and the next lowest price classes, according to one discusser, showed the over-all operating economy to be in favor of the lower-displacement powerplant; and another speaker asserts that of two engines of approximately the same piston displacement and manufacturing cost, the higher-compression higher-speed engine gives the better performance and has the greater durability.

Torque rather than horsepower per dollar is the factor of most importance that engineers are seeking, and engine design has been thought to depend more upon bearing loads imposed by inertia than upon mean effective pressures.

The oral discussion is concluded with statements as to what is regarded today as high engine-speed, and in written discussion a formula is suggested for comparing the performance ability of cars on the basis of cubic inches displaced per mile per pound of car weight. This takes cognizance of the gear ratio and the tire diameter and is asserted to give a more accurate index of ability than the cubic-inch displacement merely per pound of weight.

CHAIRMAN H. T. WOOLSON[2]:—It is fitting, in connection with every National meeting of the Society, that a prominent place should be given to papers and discussions having to do with engines, as they are the most important units we have to consider—the prime mover and source of power.

The internal-combustion engine offers an unlimited field for research, investigation and design, combining, as it does, chemical reactions taking place in the combustion-chamber, creating intense heat and high pressure; the problem of transmitting forces so developed through piston and connecting-rod to the crankshaft in a smooth, acceptable manner; the problem of water-cooling the cylinder surfaces sufficiently without overcooling and detracting from engine efficiency; the problem of lubricating the combustion-chamber surfaces which an instant before were exposed to excessively high temperature; and, in addition to all these, a multitude of intricate electrical problems having to do with high-tension currents, condensers, coils and related subjects.

Must Face and Be Guided by Facts

Our goal, as engineers designing an automobile engine, is to create powerplants that shall not be heard during operation and are free from vibration, require no attention or service over long periods, operate equally well regardless of temperature or atmospheric conditions, are reasonably economical to run and are faithful servants which shall sink their identity and not be in evidence at any time. The more nearly we can accomplish this, the more acceptable will be our powerplants for automobile use. A famous engineer, who may be present today, has often said that anyone can design an automobile; the real test of engineering ability is to design one which will operate quietly. Incidentally, we as engineers know that about 50 per cent of our time is spent in chasing noises and trying to eliminate vibration and noise.

We sometimes feel that we are making little progress in engine design. On the occasion of this 25th anniversary of the Society, we can readily make comparisons with earlier constructions. It is not necessary, however, for us to go back that far; we can look at our designs of eight or ten years ago and satisfy ourselves that we are making progress.

The improvements in shop and foundry methods and processes have made possible the production of the present-day engine, with its improvements and refinement, at a lower price than our simpler 10-year-old engine. It would be of great interest were we able to look into the future and see what it has in store for us in connection with improvements in design. Because of the economics of the situation, however, the tried and true poppet-valve engine has still endured. He would be a wise man indeed who could predict what will take its place.

We are here to discuss openmindedly and for mutual benefit facts bearing on engine-design characteristics. One thing which all engineers must learn to face, and invariably guide their actions by, is facts.

I should like to make another observation. Assum-

[1] Published in the S.A.E. JOURNAL, June, 1930, p. 719. The author is development engineer of the Chevrolet Motor Co., Detroit, and is a Member of the Society. The abstract accompanying the paper is not reprinted but the trend of the discussion herewith is summarized above for convenience of the reader.

[2] M.S.A.E.—Chief engineer, Chrysler Corp., Detroit.

ing that an engineer compiles a complete list of all the desirable characteristics he would like to incorporate in his design, he will invariably find the design limitations to be such as to render it impossible to combine all the good features. He is then faced with the problem of choosing and using those he thinks most desirable. Therefore we have engineering individuality and divergence of opinion resulting in a large variety of designs, each of which some engineer is sure is good.

We can all call to mind instances of ways in which designs may be changed slightly at absolutely no increase of costs, by the application of engineering knowledge, to produce a much more acceptable product. In the mass production in which we are engaged—perhaps at this time I should use the past tense and say were engaged—it seems like criminal negligence not to give every vital question the full advantage of all available engineering knowledge. A brilliant example of the idea I am attempting to convey is before us for discussion. It is as easy and cheap for our production departments to produce combustion-chambers one way as another, or to place spark-plugs here or there; but such slight variations, which mean nothing to the production department, may mean much with respect to powerplant economy, smoothness and power output.

H. T. WOOLSON

So I say that, in view of results to be attained, we are entirely justified in going to extreme limits in engineering research on such items. We can carry out the same reasoning in connection with many other items. We may picture before us two powerplants equal in capacity, weight and production cost but far apart in owner satisfaction; one a commercial success, the other a commercial failure. All that is lacking in one is a sufficient amount of engineering effort intelligently applied.

The Society is extremely fortunate in being able to count among its members those who have the ability and time, apart from their regular duties, to develop important contributions to engineering knowledge. I am often led to wonder with admiration at the great amount of effort some of our members are willing to contribute in connection with this work. Mr. Taub is especially to be commended for his untiring energy along these lines.

If there is any one thing in which we as engineers should be vitally interested at this time, it is economics in connection with our designs. I believe more and more we shall have to get into the economic side of our business; especially since the disastrous affair last fall, it behooves us to give the economic side close scrutiny.

I am sure we all feel that Mr. Taub has given us a very novel and interesting analysis of the characteristics of engines and powerplants in the various price classes. He has placed most of us on the other side of the fence, and I think that, if we feel that we are right, we ought to let him hear from us.

Bad Bore-Stroke Ratio Copied from England

A. LUDLOW CLAYDEN[3]:—I think we have just had the privilege of listening to a paper that will go down in the annals of the Society as one of the most important and far-reaching papers that have ever been presented before us. It seems to me that it approaches a subject of enormous importance from an angle that has not been given the consideration of which it is worthy. The thought occurred to me while listening to this paper that there have been two outstanding engineers who have always been strongly in favor of larger bores than we conventionally use. One of them, unless he has changed his opinions quite recently, is H. M. Crane. The other is F. W. Lanchester. I think those two are deans of automobile engineering on their respective sides of the Atlantic.

This paper reminded me of one of Mr. Lanchester's, which I think was read before the Institute of Automobile Engineers about the year 1909. That was a mathematical examination of the stroke-bore ratio, which was then a very important subject, and proved at least to Mr. Lanchester's satisfaction that the lightest and altogether most economical powerplant could be built by using approximately equal bore and stroke.

I still feel that the vicious system of taxation adopted in Europe is having its effect even today on American-made automobiles. When I came to this Country approximately 20 years ago, the development of the small bore and long stroke in the comparatively high-speed engine had progressed considerably farther in Europe than it had in this Country; but about 1914 the shoe was on the other foot and development here began to lead the rest of the world. But a great deal of copying of European designs was done between 1910 and 1914. That bad stroke-bore ratio was taken along with many other things, some good and some bad, and we have never been able to throw off the shackles of it.

Troubles Caused by High Temperatures

I have always been an advocate of the large-bore short-stroke engine, because I have felt certain that it was easier to make that perform smoothly and have been afraid of the high-compression high-speed engine for the reason Mr. Taub mentions; that is, increasing temperatures, which will bring about metallurgical difficulties.

Fuels can be made to take care of even higher compressions than we are using now. That is merely a matter of cost. The ingenuity of the oil industry in producing high-compression fuels is by no manner of means exhausted, but higher temperature will necessarily go with them, and somewhere there is a point beyond which it does not pay to go. A lot of ground was gone over long ago on this one question, and we are going over it again now. When engine outputs were first increased very considerably 15 or more years ago, we had valve difficulties, which were overcome by the introduction of new valve-steels, and everybody forgot about them. We had difficulties because of excessive reciprocating weight, which were overcome to a great extent by the introduction of light-alloy reciprocating parts and very greatly improved designs; but probably we have gone about as far in that direction as we can go, and, by aiming for higher and higher temperatures and higher and higher speeds, designing engineers are

[3] M.S.A.E.—Research engineer, Sun Oil Co., Philadelphia.

shifting an increasing share of their burden to the shoulders, first, of the metallurgists, and, second, the producers of fuels and lubricants.

Speaking for the latter two groups, we have carried a great deal of the load for the designing engineer and have sometimes felt that he was asking us to carry an unfair share, as Mr. Taub pointed out very well; and, while we are willing, we believe that a little pause in increases would be very helpful to the industry at large.

ALEX TAUB:—I am pleased to acknowledge that Mr. Crane's teachings are behind every thought contained in the paper.

No Longer Restricted by Manifold Design

ROBERT N. JANEWAY[4]:—Mr. Taub has pointed out that one of the major evils inherent in the high-speed small-displacement engine is the sacrifice of efficiency in mixture distribution with conventional manifolds. Relatively high velocities are fundamental in the efficient distribution of wet mixtures. Since high velocities in the manifold are incompatible with high volumetric efficiency, the high-speed engine involves a compromise between power and economy. The predominating demand for the maximum possible performance invariably results in the sacrifice of distribution for the sake of power in the high-speed engine.

It is needless for me to repeat the consequences in engine durability which Mr. Taub has discussed so comprehensively. I am in full sympathy with Mr. Taub's indictment of the small-displacement high-speed engine and therefore am sorry to diminish the force of any of his well-founded arguments. However, these arguments are so many and in the main so unanswerable that I feel that the loss of one argument against the high-speed engine will not alter the picture.

A. LUDLOW CLAYDEN

Mr. Taub's paper is necessarily limited to the present state of the art, over which he unquestionably has complete grasp. In this day of rapid progress, however, the given state of any art is extremely transitory and subject to change with very little notice. I believe that the limitations of present-day manifold design need no longer be accepted. I say this without hesitation because I have been in close touch with developments based on a new principle in mixture handling which has successfully defied every convention of manifold design and achieved results impossible to the conventional manifold.

This new principle, by absorption and concentrated heating of the liquid fuel as it leaves the carbureter, converts the fuel into dry gas, hence the subsequent distribution of the mixture is independent of manifold velocity and makes possible complete freedom in designing the manifold for the maximum volumetric efficiency. Of utmost significance is the fact that the rise in temperature of the mixture passing through the manifold is considerably reduced as compared with the conventional manifold, and herein lies the uniqueness of the basic principle. It means that a gaseous mixture is generated, not only without sacrifice of volumetric efficiency but actually with a decided increase in volumetric efficiency.

It is also pertinent that the converted manifold eliminates the sensitiveness of distribution to variations in production, which Mr. Taub emphasizes in connection with conventional manifolds. Since this development is now available to the industry, it should no longer be necessary that the high-speed engine suffer from distribution troubles. However, the larger lower-speed engine, even though it is aided by higher possible manifold velocities, leaves much to be desired as to uniformity of distribution. By taking advantage of this new principle in connection with the lower-speed engine, the greatest possible result per dollar unquestionably will be obtained.

Make Material Work Harder

H. E. MAYNARD[5]:—I do not think that any engineer or business executive in the automotive industry can find fault with the first statement laid down in Mr. Taub's paper, which is, "The fundamental rule of result per dollar is the major principle of economics on which the future of this industry is founded." There is some possibility that the interpretation in the minds of the engineers might modify the definition of "result per dollar." This must, in the last analysis, be interpreted from the viewpoint of the ultimate consumer, based on his reaction as to what he believes to be of primary importance in connection with the article for which he is spending his money. Therefore it may be that the same requirements or desirable features in the low-priced-car field may not apply equally well in the high-priced field. Consequently a feeling exists that it is impossible for engineers to lay down any set rules or formulas which shall influence the buyer contrary to his own impressions.

The trend in the past years undoubtedly has been toward a decrease in weight per horsepower. We can all remember when for a period of time 2000 r.p.m. at full throttle was regarded as a very creditable engine performance. Today 3000 r.p.m., under wide-open conditions, can be maintained for long periods without any detrimental effect on a well-designed automobile engine. This has been brought about by refinements such as improved design of bearings, use of full-pressure lubricating systems, better valve materials and design, treatment of valve seats by hardening or chilling processes, the use of aluminum pistons, strict attention to water-cooling and kindred improvements.

Engineers in the last decade have set a goal of increased power at less weight per horsepower, overcoming difficulties as they arose by intensive study and intelligent design and research, which has spelled progress all along the line. Our industry is not alone in its endeavor to decrease weights. Builders of stationary, aircraft and marine powerplants have been working in this direction for some time. A notable example of this tendency that has come to attention recently is the Packard air-cooled Diesel engine, in which it was found possible, by untiring engineering effort, to overcome the well-established idea that Diesel engines had to be extremely heavy. It was found possible to design and

[4] M.S.A.E.—Consulting engineer, Detroit.

[5] M.S.A.E.—Assistant chief engineer, Chrysler Corp., Detroit.

build a Diesel engine sufficiently light to make practical an air-cooled powerplant and at the same time obtain operating economies equal to those of the largest stationary Diesel on the market.

A lighter and consequently smoother engine, capable of higher speeds, permits the use of lighter units such as transmissions, rear axles, frames and springs, resulting in a lighter and less expensive automobile. Engineers have unconsciously adopted the slogan: "Make a pound of material work harder." And mass production has made it possible for us to add to this slogan: "And sell it cheaper."

The average automobile buyer today is expecting for his dollar, first, style and eye appeal; second, outstanding performance; third, smoothness and quietness in operation; fourth, economy in operation; fifth, durability.

Over-All Economy Favors Small Displacement

It does not seem that superior performance, which is so much appreciated by the average car owner, should be sacrificed to too great an extent to place undue emphasis on maximum high-speed performance. While the *PV* factor may be high for top speeds, we should consider that the average car is driven at maximum speeds less than 5 per cent of the mileage during the life of the car. It does not seem logical to make a sacrifice on 95 per cent of the operation so as to protect the 5 per cent; rather, we should put forth an effort to provide for the occasional high *PV* by close attention to bearing designs, lubrication and other contributing factors.

A recent tendency in car design is to keep down top engine-speeds approximately 15 per cent by the use of four-speed transmissions, resulting in many advantages with respect to durability, smooth performance and economy of powerplants, at the same time satisfying the requirements from the standpoint of acceleration and hill-climbing which must be met because of the demand of the public.

In connection with the operation of several fleets of cars in our own line in the Nos. 1 and 2 price classes, which we have had occasion to check closely, we have found the trend of over-all operating economy to be in favor of the lower-displacement or No. 2 price-class powerplant. In this case less trouble is experienced with the various units.

I should like to emphasize Mr. Taub's contentions regarding the importance of close cooperation with the foundry, forge and machine shops. Only insofar as an engineer is willing to take off his coat and investigate shop problems from the shop man's standpoint will he achieve the greatest success in his design as regards economy and production. There is no question that cooperation in manufacturing is one of the most vital points to be considered from the standpoint of cost; more and more the shop is helping us out and giving us the advantage of economical manufacturing of designs which otherwise would be detrimental to the cost of the product.

R. N. JANEWAY

Evils of Crowding Engine Design

MR. TAUB:—Mr. Maynard stresses the point that increased horsepower per pound has been and is an engineering ideal. It is distressing to note that each year the newer model of a given type incorporates a larger engine than that of the previous year. These engine-size increases are made in an effort to "unload" the engine. Unfortunately, this type of increase usually is made by crowding existing conditions, which crowding quite often offsets any gain made in engine size.

H. C. MAYNARD

Mr. Maynard intimates that the small displacement represents the over-all economy. A wide and varied experience on our part leads us to the opinion that this is an entirely erroneous picture, the facts of which form the body of the paper.

Mr. Maynard told us that the company he represents obtains smoothness, durability, economy and performance with the small high-speed engine, but he also admitted that when a four-speed transmission was incorporated to reduce the engine speeds it ran smoother, quieter and better. Obviously, this improvement was needed or it would not have been so apparent.

The buyer wants durability, and there is no doubt that you cannot give him durability with oil temperatures ranging from 275 to 340 deg. fahr., which are the temperatures for which we are now headed.

Since I have little or nothing to do with the higher-price classes, it is quite all right for me to criticize. Many organizations are now considering or using the in-line eight-cylinder engine. Many engineers are forced by circumstances to deal with executives who prefer to do the engineering in the front office, starting the designing engineer off by telling him he can have only so much room for the engine. The result is that some of the principles of engine design are sacrificed; you have so much room, therefore you take the small bore, and if the stroke is too long you compromise on a few less cubic inches of piston displacement. Not only that; still believing you can do everything with the small engine, you leave the water out between the valves because there is not room enough to put in water. These are the things that must be given consideration, for they constitute the sins of commission.

You cannot make a small engine compete well with a large engine of the same basic design, and you cannot make a crowded engine work at all in the hands of the public. When you sell a man a car to drive at maximum speed, with the good roads and the number of cylinders that we have today, you are inviting him to drive it to the maximum, and if the car will not run consistently you have not done your job. You may think that the car is going to be driven 80 to 85 per cent of the time at lower speeds and that the design will be safe,

but if 10 per cent of your customers find you out, it will be just too bad.

FLOYD F. KISHLINE

Torque More Important than Horsepower

FLOYD F. KISHLINE[6]:—Mr. Taub's very valuable presentation certainly represents a great deal of work. The nature of the paper and its projected thoughts, however, seem to me to be somewhat on the defensive from the start. Many points are brought out in it that we must face as facts which are already familiar.

One impression I gained from it is that I have had the wrong opinion, apparently, about one of our best known four-cylinder automobiles that seems to fit very accurately into the specifications laid down for an ideal car; in fact, it is slightly better in one respect, because, in addition to having large displacement for its weight and low engine-speeds, the unnecessary step of using aluminum pistons has been taken.

We have thought that the fundamentals of an engine design depended not so much on the mean effective pressures as upon the bearing loads, which are affected more by inertia than they are by pressures. Our thought has been that the factor that is most important per dollar is engine torque rather than engine horsepower. Most of us know how to increase the horsepower of any given engine substantially if that were the only thing required. If we get sufficient torque from an engine, together with the durability to be expected from sound design, sufficient horsepower usually will be found to come automatically.

High Compression Gives Fuel Economy

However, the average types analyzed seem to indicate that, together with the many advantages of a large-displacement engine, we must consider economy, which begins with pounds of fuel consumed per brake horsepower-hour. If we make the engine exceptionally large and use a low compression-ratio to keep the torque within the capacity of our clutches, transmissions and axles, we expect much poorer economy than if the compression is kept up, whether or not the engine be made smaller because the compression is increased.

One thing about Mr. Taub's Fig. 4 that I did not clearly understand is how he found that cars in the No. 1 price class showed an average of 23.5 miles per gal. at 20 m.p.h. From our experience that seems to be a very high average.

The expression of low speed and large displacement or high speed and small displacement, as applied to automobile engines, seems to me to be relative. Perhaps the engine giving representative performance of today would years ago have been regarded as an extremely heavy-duty and rather high-speed engine, which indicates generally that progress has carried us in the direction of more intensive development of each cubic inch of piston displacement rather than of the use of more cubic inches, which in my opinion is perhaps the line of least resistance.

Cheaper Materials in Low-Speed Engine

Regarding the higher temperatures and their ill effects in the high-speed type of engine, I should like to point out that in most cases, when the engine is made large and operated at lower speeds, the temperatures being lower because of lower compression, cheaper valve materials must be employed for economy, and other economical measures have to be taken, so the net result is that the life of those parts critically affected by high temperatures is no greater than in the high-speed type.

Our experience has been that the subject of valve timing is comparatively unimportant. Exhaust valves opening 40 deg. before dead center can be employed in an engine producing approximately 0.4 hp. per cu. in. and 0.7 ft-lb. per cu. in., this engine developing its maximum horsepower at about 3300 or 3400 r.p.m. The top horsepower of this engine is very slightly improved by opening the exhaust valves 50 deg. before dead center, and when that is done the maximum torque is considerably decreased.

As conditions have been and are, it seems to me that at least as many main-bearing failures have occurred in the large slow-speed engines as in the other type. That, I think, brings us back to the economical measures that must be employed in the larger engine to meet the cost requirement. Perhaps the oiling system is not as complete, and even in some cases the materials used in bearings are not of quite the high quality of those used in other types of engine.

We have found in some experiments that oil temperatures can easily run very high in the slow-speed engine; that is caused more by the bearing loads than by the rubbing speed. Oil temperatures can be reduced somewhat below the danger point by utilizing cold-water jacketing to a greater extent, so as to take the heat out of the engine rather than to ignore that which finds its way into the oil.

A. G. HERRESHOFF

MR. TAUB:—Mr. Kishline has given voice to a statement usually credited to the uninitiated, which is that the lower-price classes use inferior materials. It is true that emergency material is not used, simply because emergency is not permitted to arise. If, in his price class, the heat and load stress is such as to make absolutely essential the use of the maximum of metallurgical advantage, why should that price class feel superior? It is quite obvious from his statement with regard to gasoline mileage that he has not approached the study of the cars in the lowest-price class with an open mind.

Mr. Kishline states that valve timing is relatively unimportant. In the past he has stated that spark-plug position and combustion-chamber shapes were relatively unimportant. Our experience does not agree.

[6] M.S.A.E.—Assistant chief engineer, Graham-Paige Motors Corp., Detroit.

CHAIRMAN WOOLSON:—I think it would be interesting to see how this analysis applies in the truck field. If I am not mistaken, the *PV* and r.p.m. and so forth run excessively high for a truck, which is more of an economic problem even than the lowest price passenger-car.

High-Compression High-Speed Engine Superior

A. G. HERRESHOFF[7]:—It happens that our company makes two engines of just about the same displacement, both used on passenger-car work and truck work. One of these engines has relatively low compression and low speed and the other relatively high compression and high speed. Unfortunately for the sake of comparison, one is a four-cylinder and the other a six-cylinder engine, but it is interesting to compare them.

The low-compression engine makes its maximum power at about 2800 r.p.m.; the relatively high-compression engine at about 3400 r.p.m. The cost per horsepower of manufacturing the two engines is just about the same. There is not much doubt in our minds as to which engine has the longer life, the greater durability, and gives the better performance; and that is the higher compression high-speed engine.

The cause of the low-speed engine has been very ably presented. I think the cause of the high-speed engine might be well presented by showing some of the disadvantages of low speed. What we are seeking is not the horsepower of the engine; it is the performance of the vehicle. To illustrate, if in a given vehicle we increase the engine weight, we increase the car weight and detract from the performance of the vehicle. The use of the lower-compression low-speed engine, necessitating, as it does, a larger bore, would make a heavier engine. This would mean a heavier chassis and again a larger bore to bring the performance up, thus creating a vicious circle.

However, one principle that Mr. Taub mentioned with which we can all very heartily agree is that of moderation in all things, especially in large production; but I do not believe that Mr. Taub intended us to take this advice as we would the advice that, because of wear and tear on our nerves, we should never play a game of golf in less than 100.

What Is Meant by High Speed

MR. TAUB:—It is rather unfortunate that Mr. Herreshoff found it necessary to bring into this discussion the fact that his company's low-priced six-cylinder engine makes a better truck engine than its original four-cylinder engine. Surely he does not believe that the satisfaction obtained by this interchange of powerplants was due to the fact that the six was smaller than the four. I am sure it is unnecessary to point out the natural advantages of a six-cylinder engine for commercial use.

If Mr. Herreshoff will continue his observations I am sure that he will discover that increased piston displacement coupled with the natural advantages of a six-cylinder engine will result in still more satisfaction, to the point where he may be enabled to play his golf below 100 without having nerves to fray.

The point that is most apparent in this discussion is that those who have taken part in it do not have in mind the engine speed to which I have reference. The engine against which my paper is directed has a speed of 4000 r.p.m. That is a high-speed engine. High-speed engines that operate at 3300 r.p.m. are still rational. The point I am driving at is that we are all looking upward beyond the 4000 mark. This paper was written as a cautionary analysis to advise against that kind of an engine.

Large engines will tend to increase weight. If we have an engine of 230-cu. in. displacement and want to increase that to 260 cu. in., it is not at all difficult to add the 30 in. with a weight increase of 5 lb., and the poor old chassis will never know the difference.

I am not talking about displacing a 150-cu. in. engine with a 300-cu. in. engine, but about getting that last 10 or 15 per cent in power that we want by increasing the engine size rather than crowding it into an already crowded condition.

MR. HERRESHOFF:—I can agree with Mr. Taub that 4000-r.p.m. engines are high-speed engines, but I well remember that about 15 years ago I wrote to my father, who is a well-known engineer, and told him that I was working on the design of an engine to run at 3000 r.p.m. He wrote back that I would better not talk about impossible things but about things that we all knew would work. It seems to me it is only a question of day and age.

WILLIAM R. STRICKLAND[8]:—A speed of 4000 r.p.m. is not at all exorbitant. I know of an engine that does as much as 4600 r.p.m. in second gear, or when we want it to.

CHAIRMAN WOOLSON:—The 30 cu. in. of additional displacement would have some effect on torque, which is the factor on which we base our transmissions, axles and so forth.

[7] M.S.A.E.—Director, truck engineering, Chrysler Corp., Detroit.
[8] M.S.A.E.—Assistant chief engineer, Cadillac Motor Car Co., Detroit.

The Autogiro Analyzed

(*Concluded from p.* 262)

equalizing lift, the blades on one side rise higher than do those on the other side. The resultant disc therefore tips. In machines designed with American engines, the tipping is to the left of the pilot. Because of coning, inertia and other somewhat complex forces set up in the rotor system during flight, the disc also tilts back. Therefore, the resultant thrust on the rotor as a whole is not perpendicular, and it is customary to offset the mast slightly to counteract the average condition. We use a slight tilt laterally.

Thermal Expansion *in Automotive-Engine Design*

Cleveland Section Paper

By FRANK JARDINE[1]

When ferrous metals and aluminum alloys are combined in a structure that is subject to considerable changes in temperature, as is an internal-combustion engine, the different rates of thermal expansion of the two metals are likely to cause trouble.

Various methods of dealing with this problem are outlined, the chief of which includes the combination of a recently developed aluminum alloy having an unusually low coefficient of thermal expansion and a high-nickel alloy of cast iron which has a higher coefficient of expansion than most ferrous metals.

The new low-expansion aluminum alloy is said to eliminate the necessity for split-skirt pistons.

The discussion brought out various points in regard to the machining, application and cost of the two new alloys and experience with pistons made from the older aluminum alloys.

TODAY a problem exists in the field of automotive engineering which should receive greater engineering consideration than it has been given. This is the problem that arises when several different metals, each having a coefficient of expansion different from those of the other metals, are included in a single structure. Unquestionably this problem exists in many phases of engineering, but this paper will deal only with automotive-engine design.

It is common knowledge that expansion or contraction does take place with any change in temperature. Probably the most familiar example of this phenomenon is the rise and fall of the mercury column in the ordinary thermometer.

Expansion has at times caused very troublesome problems in the manufacture of certain articles. One example comes to mind from the electric-light-bulb industry. It is necessary that a tight joint be maintained between two wires that pass into the bulb and the glass of the bulb at any and all temperatures. An alloy finally was developed from which wire is made that has the same coefficient of expansion as the glass.

Then, again, the surveyor is provided with chains made from invar steel, an alloy which has almost no expansion, thereby eliminating troublesome calculations which formerly were necessary because of variation in the lengths of the chain at different temperatures.

Many more examples might be cited in which expansion plays a part in engineering problems. In some instances the particular expansion coefficient of an alloy has been beneficial, while in other instances the designer is at all times confronted with the problems which are created by thermal expansion.

Table 1, showing the thermal expansion of a few of the metals used in automotive construction, is given to provide a clear picture of the magnitude of the expansion of different engineering materials. It can readily be seen from the figures that the expansion of the different materials varies over a wide range and that a combination of these materials built into a machine has the possibility of creating stresses of considerable magnitude because of the dissimilar expansion coefficients of the materials.

Let us consider, as a simple example, a thin ring of invar steel. Within this ring is placed a solid disc of forged magnesium, in such a manner that there is no clearance between the disc and the ring. The invar is so thin that it is assumed that all distortion will take place in the ring, consequently there will be no compression of the magnesium disc. Increasing the temperature of the disc and ring 100 deg. fahr., it is found that the inner diameter of the invar ring has been increased 0.001384 in. per inch of diameter. As the elastic modulus of the invar steel is 21,000,000, the stress of the fibers on the inside diameter of the ring will be equal to the product of the unit deformation 0.001384 and the modulus 21,000,000, or 29,064 lb. per sq. inch. An extreme condition was used in the above example, but stresses would be set up in any combination of materials in varying degrees depending on the coefficients of the materials and the temperature changes.

Aluminum Causes Problems

If it were possible to build up a design using only one alloy throughout, the problems arising from expansion would be less. However, the use of aluminum alloys has become such general practice in engine design that it is necessary to consider the expansion of this material when used in conjunction with other materials.

The outstanding advantages of aluminum alloys which have brought about their use in the automotive field are the high heat conductivity and the low specific weight.

TABLE 1—THERMAL-EXPANSION COEFFICIENTS OF AUTOMOTIVE METALS

Material	Coefficient of Expansion, per Deg. Fahr.
Aluminum	0.0000123
Lo-Ex	0.0000105
Magnesium	0.0000145
Cast Iron	0.00000589
Steel	0.00000734
36-Per Cent Nickel Invar	0.00000066
Bronze	0.00000995
Babbitt	0.00001210

Since the piston is both a reciprocating member and a medium of heat transfer, the greatest advantage results in the use of aluminum for this particular part. In making pistons from aluminum, the designer must deal with a problem brought about by the coefficient of expansion of the piston material differing from that of the cylinder in which it operates. As previously pointed out, the expansion of aluminum for a given temperature rise is greater than that of iron. For this reason, the ordinary aluminum-alloy trunk-type piston requires approximately twice the clearance of an iron trunk-type piston. Experience has shown that when an aluminum piston of this type is cold it tends to develop an undesirable noise known as piston slap. In order to eliminate this noise, most engineers have resorted to pistons of unconventional types which operate quietly. To secure this quiet operation it is necessary to adopt certain features which make a more complicated and expensive product.

The conventional trunk-type piston, compared with existing unconventional pistons, has longer life and better heat conductivity, is simpler to manufacture, costs less and is lighter in weight. Long life can be secured in a trunk-type aluminum piston only when it is initially fitted with clearances that are comparable with those used in an all-cast-iron installation. In order to use the desired close clearances, the coefficient of expansion of the aluminum piston alloy must approach more nearly that of the material from which the cylinder-block is made.

Properties of New Aluminum Alloys

To secure a satisfactory relationship between the expansion of the piston and the cylinder, it was necessary to develop a new aluminum alloy having an expansion coefficient more nearly the same as that of common cast iron. For the past several years the metallurigcal department of the Aluminum Co. of America has been putting forth every effort to develop such an alloy. An alloy having the same expansion as cast iron has not yet been developed, but an aluminum alloy, commercially known as Lo-Ex alloy, has been developed which has an appreciably lower expansion than the more common aluminum-copper piston alloys. This alloy analyzes approximately as follows:

Silicon	14 per cent
Copper	1 per cent
Magnesium	1 per cent
Nickel	2 per cent

Its physical properties are:

Tensile Strength, minimum 30,000 lb. per sq. in.
Elongation 0 to 1 per cent
Brinell Hardness 90 to 120
Coefficient of Expansion 0.0000105 per deg. fahr.

The specific weight of this alloy is approximately 10 per cent lower than that of the present 10-per cent-copper piston-alloys. The weight saving due to this lighter alloy is especially desirable in aviation-engine pistons, where the total engine weights are further reduced by a proportional decrease in the weight of the counter balances. The hardness is slightly less than is sometimes specified for the more common aluminum-alloy pistons; however, exhaustive tests carried out both in the laboratory and in production engines show that pistons of this material have longer life than harder pistons of other alloys.

The thermal properties of this alloy are considerably better than those of common aluminum piston alloys. Owing to the superior thermal properties and the relatively lower expansion coefficient, this alloy is being used quite extensively in ordinary cast-iron cylinder-blocks.

Iron Alloy Having High Expansion

As has been previously mentioned, the coefficient of expansion of the Lo-Ex is not the same as ordinary cast iron; therefore, it is desirable to use Ni-Resist iron, which has virtually the same expansion coefficient as the Lo-Ex alloy, for the cylinders or sleeves. This material is an austenitic cast iron developed by the International Nickel Co. and has the following analysis and physical properties:

Chromium, minimum 1.5 per cent
Silicon, 1.5 to 2.5 per cent
Manganese, minimum 1.25 per cent
Nickel, minimum 12.5 per cent
Copper, minimum 5.0 per cent

Total Carbon 2.8 to 3.0 per cent
Tensile Strength 20,000 to 35,000 lb. per sq. in.
Elastic Limit 15,000 lb. per sq. in.
Brinell Hardness 130 to 170
Elongation 2 per cent
Coefficient of Expansion 0.0000100 in. per deg. fahr.

Using this combination of Lo-Ex alloy and Ni-Resist iron for pistons and sleeves eliminated the necessity for piston-expansion control and the use of flexible pistons, because all materials expand at virtually the same rate. The result is that the Lo-Ex piston will be of the conventional trunk type, fitted with a clearance such as

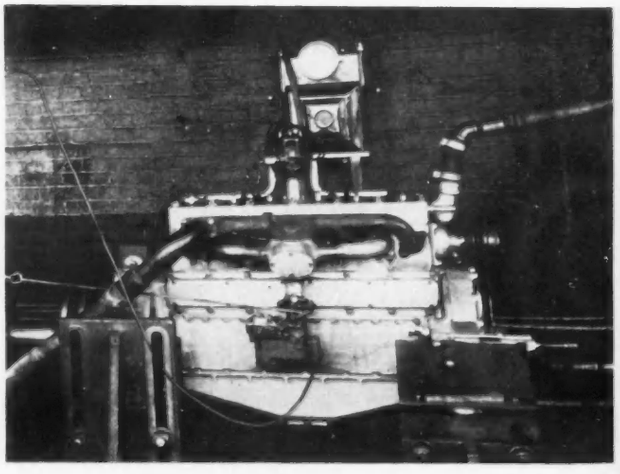


FIG. 1—ALUMINUM ENGINE UNDER TEST IN LABORATORY

The First Test of Lo-Ex Aluminum-Alloy Pistons in Ni-Resist-Iron Cylinder-Liners Was Made in This Engine

previously was possible only in the all-cast-iron installation. This piston will be free from loads caused by excessive piston expansion, eliminating the high friction at elevated temperatures which causes increased wear. The trunk-type piston also has the added advantage of a large bearing area, thereby reducing the unit bearing loads to the minimum.

For the last two years the engineering department of the Aluminum Co. of America has been testing this new combination of low-expansion pistons and iron sleeves having equal expansion. The tests were divided into two distinct groups. The first tests were made in the laboratory, using the 3¼ x 5 in.-aluminum engine shown in Fig. 1.

This engine develops 75 hp. at 3000 r.p.m. The figure shows the general construction of the engine, with aluminum cylinder-head, aluminum crankcase and aluminum cylinder-block case separately. The block is very short and the sleeves project below the block proper about one-half their length. This block, as originally built, was fitted with ordinary cast-iron sleeves and used a piston having an insert which controlled the expansion. The ordinary iron sleeves were replaced by sleeves made from the high-nickel Ni-Resist iron which were shrunk into the block with about 0.003 in. total shrink. After assembly, the sleeves were ground to size. The engine was fitted with permanent-mold trunk-type Lo-Ex alloy pistons having 0.0025 to 0.003 in. clearance.

Satisfactory Tests of the Combination

After running the engine for 200 hr. at three-quarter load and 2500 r.p.m., the pistons were removed for inspection and the wear was found to be very uniform throughout the length of the skirt. The average skirt wear was 0.0004 in. and the average cylinder wear was 0.0003 in. At no time did the engine show a tendency to lose power because of tight pistons.

The second test was also carried out in the laboratory, using a heavy-duty truck engine equipped with removable sleeves. This test was made chiefly for the purpose of testing a wet Ni-Resist-iron sleeve in conjunction with a block made from ordinary cast iron. The sleeve and block assembly of a similar engine are shown in Fig. 2.

The water is retained at the top by means of a thin, graphite-covered asbestos gasket. This gasket serves as a seat for the sleeve as well as maintaining a water-tight joint. The lower two gaskets are round sections of rubber in V-grooves. The upper rubber gasket is intended to make the joint water-tight. The lower gasket is installed as a safety measure to eliminate the possibility of water reaching the crankcase. The groove between the rubber gaskets is drilled to allow any leakage to drain outside the engine. The bottom portion of the sleeve is a slip fit into the block and has a clearance of approximately 0.0005 in. per in. of diameter, whereas the shoulder at the top of the sleeve is fitted with a clearance of approximately 0.00075 in. per in. of diameter.

It was thought that trouble might be experienced with the high-expansion sleeves fitted so closely in the ordinary iron block. No trouble resulted during the dynamometer tests, even though the Lo-Ex pistons were fitted with the same clearances used for the original cast-iron pistons. The results of these tests indicate that the problem of expansion in connection with the aluminum piston has been quite satisfactorily solved by the Lo-Ex-Ni-Resist combination.

While the piston problem has been the most difficult, other problems still exist. Following the use of aluminum pistons came the aluminum connecting-rod. The demand for aluminum rods is the result of a desire on the part of designers to lighten further reciprocating and rotating parts. Early aluminum connecting-rods were frequently made in the steel-rod dies. This practice was probably due to the fact that the strong aluminum alloy compared favorably in strength with the ordinary low-carbon forging steel. As time went on, it was found that the forging characteristics of the aluminum alloy were such that special dies were necessary in all instances. Experience also showed that the aluminum rod, if properly designed, would serve as satisfactorily as the steel. The Aluminum Co. of America has made an elaborate study of the aluminum rod and, by combining the information acquired in manufacturing many thousands of rods with certain theoretical aspects of design, empirical formulas have been arrived at which substantially guarantee a satisfactory design. The problem of making a satisfactory aluminum-connecting-rod design now is merely a matter of substitution and of a certain amount of engineering ability.

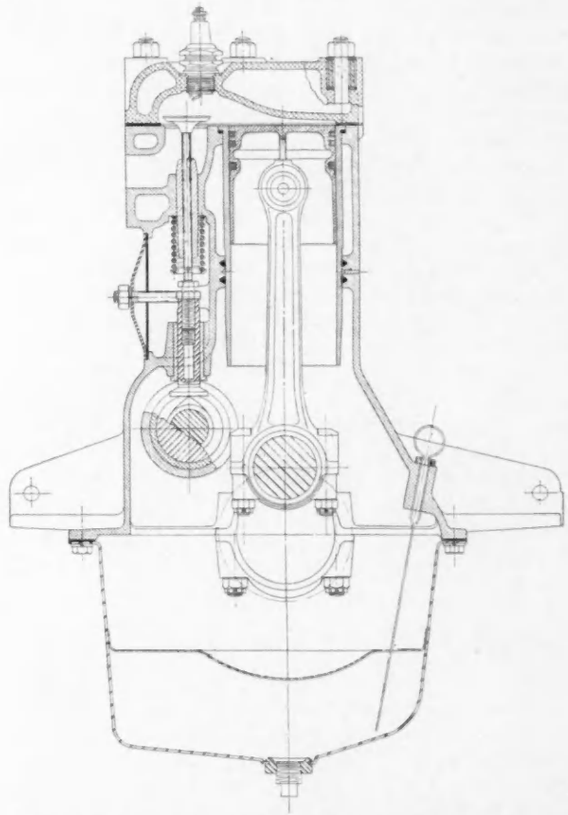


FIG. 2—TYPE OF HEAVY-DUTY MOTOR-TRUCK ENGINE IN WHICH FURTHER TESTS WERE MADE

Aluminum Connecting-Rods with Steel Caps

In the aluminum-rod design the problem of expansion exists as in connection with the aluminum piston. Even in the face of the undesirable expansion-feature which

will be discussed, the advantages of the aluminum rod are outstanding. In some instances the difference in expansion of the aluminum rod and the crankpin gives an increased clearance between the rod bearing and the crankpin operating under conditions which may result in a noisy bearing. In other instances the rods have been fitted so carefully and accurately that the tendency to become noisy is eliminated; yet it is a problem that exists where ordinary production methods are used. This tendency of the big end to get noisy because of excessive clearance has been very satisfactorily taken care of by the use of a steel cap in conjunction with aluminum rods in passenger-car engines and is now very common practice.

The Stutz Motor Car Co. first adopted the steel cap and found that the expansion of the big end of the rod was reduced to an extent that assured absolute quietness at any and all temperatures, making this construction compare favorably with the all-steel rod. The steel cap also removed the trouble sometimes experienced when the all-aluminum rod was initially fitted too tight; namely, freezing of the rods on the pins and difficult starting in sub-zero weather.

The curves of Fig. 3 show diagrammatically the thermal expansion of an aluminum-rod big-end bearing, respectively with an aluminum cap and steel bolts, a steel cap and steel bolts and an aluminum cap and aluminum bolts. It will be noticed that the average diametrical expansion has been reduced approximately 27 per cent by the use of the steel cap.

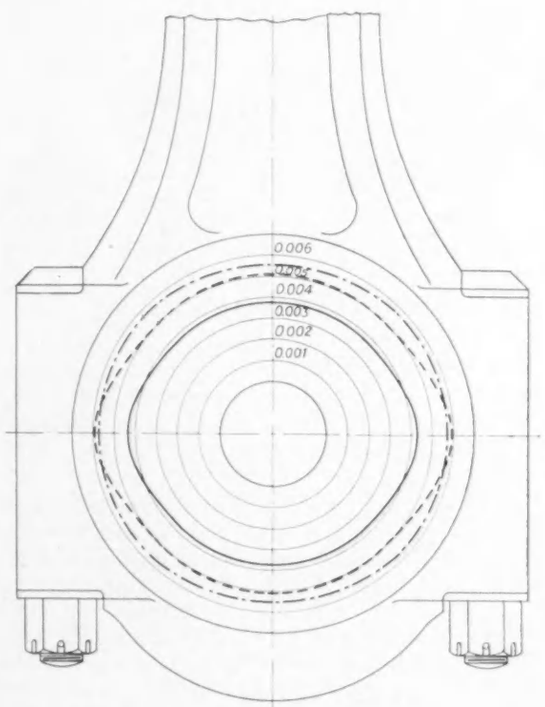


FIG. 3—DIAGRAM SHOWING EXPANSION AT THE BIG END OF AN ALUMINUM-ALLOY CONNECTING-ROD

The Small Heavy Circle Is the Base Line to Which the Light Scale-Circles Are Referred. The Solid-Line Oval Shows the Expansion When the Rod Is Fitted with a Cast-Iron Cap and Steel Bolts; the Dotted Oval Represents the Expansion with an Aluminum Cap and Steel Bolts; and the Dot-and-Dash Circle Represents the Expansion When Only Aluminum Is Used

To date the use of the aluminum connecting-rod with steel caps has been confined to passenger-car engines. It appears that the need for steel caps on the large rods used in industrial engines is not great. The steel cap is unnecessary primarily because these engines usually have cooler big-end bearings than do the passenger-car engines; therefore the unit expansion is less. In addition, there seems to be no necessity for fitting the rods with the extremely close clearances which are required in passenger-car engines.

The primary advantage in the use of the aluminum rod, as mentioned before, is in the reduction of the rotating and reciprocating weights. It is found, however, that the thermal characteristics of aluminum tend to make its use still more desirable. There seems to be very little question that a much-cooler big-end results from the use of aluminum rods. It is an irrefutable fact that the big-end bearing generates a considerable amount of heat. One purpose in supplying excess oil to this bearing is to help to remove the generated heat through the medium of the oil. Unquestionably this method is quite satisfactory, yet it seems highly desirable that the rod itself should help to dissipate this heat. The aluminum rod may run at a slightly higher average temperature throughout than does the steel rod. It will be found, however, that the big-end bearing is approximately 25 to 50 per cent cooler in degrees fahrenheit; whereas the shank and small end of the rod will operate at possibly 25 per cent higher temperatures. The difference in the temperatures of the big-end bearing can be demonstrated by fitting an aluminum rod and a steel rod to a short steel shaft and immersing the big ends in oil at 500 deg. fahr. It will be found that the babbitt in the steel rod will melt out and the babbitt in the aluminum rod will remain intact. This test indicates the ability of the aluminum rod to dissipate heat from the big end. It has been found possible to replace steel rods, which have given a great deal of trouble in the field from burned-out bearings, with aluminum rods and eliminate this trouble because of the fact that the aluminum-rod bearing is cooler.

Fit of Piston Pins in Aluminum

The piston-pin end of the rod ordinarily does not present any difficulties when considered from an expansion viewpoint. This is due primarily to the relatively low temperature and the small diameter of the pin. An assembly problem exists at this point, resulting from the use of the steel pin with the aluminum piston. The expansion of the pin is so different from that of the piston-pin bosses that excessive clearances sometimes are encountered and a noisy piston-pin is the result. This problem is taken care of usually by fitting the pin with a slight shrink in the piston boss and allowing the pin to float freely in the rod. Such an assembly allows the pin to turn in the rod while the engine is cold. After the piston is heated up, the clearance of the pin in the bosses reaches a point which allows the pin to float freely without danger of noise.

Naturally the ideal combination would be one wherein all materials would have the same coefficient of thermal expansion. Such a combination was common in the past, when all materials used were ferrous alloys. The advent of aluminum alloys and the extreme desirability of having pistons made from aluminum resulted in the problem that has been discussed in the foregoing. Here again is a use for a material having a coefficient of ex-

pansion near to that of aluminum, provided the strength, toughness, and wear resistance of this material are satisfactory for piston-pin service. Laboratory tests are in progress on piston-pins of Ni-Resist iron, but they have not gone far enough to justify definite conclusions or recommendations.

Structural Parts of Aluminum

Aluminum crankcases and oil-pans have been used for many years in automotive engines. In virtually every instance the troubles encountered were of a very minor nature and really were mostly a foundry problem. These problems were due primarily to the extreme amount of shrinkage during solidification, which is due to the high expansion-coefficient of the aluminum alloy. As time went on, foundry practice was modified and alloys improved. It is found that at present aluminum crankcases and oil-pans give no particular trouble, and their service life compares in all respects with that of any other material or combination of materials. Probably in operation these parts are free from expansion troubles because of the lower temperatures and freer fits, even though the crankcases are used in connection with iron cylinder-blocks.

Within the last few years the aluminum cylinder-head has become popular. The desirability of the aluminum head is due almost entirely to the high thermal conductivity of the material. Localized hot spots are eliminated, and average temperatures are lowered very much. These features are quite desirable owing to the increasing use of the high-compression engines. Aluminum alloys have proved very advantageous for this particular use. We find, however, that trouble due to expansion is encountered in the poppet-valve engines having conventional cast-iron cylinder-blocks; not to any great extent in the individual heads used in the Knight sleeve-valve engines. The different expansion-coefficients of the two materials, in conjunction with the generally higher temperature of the head, introduce certain problems which should be considered.

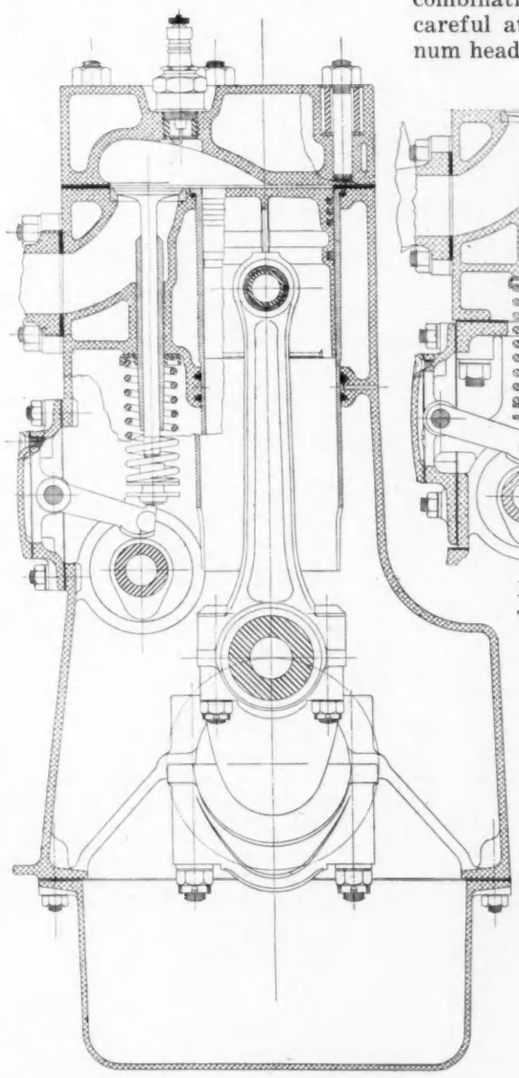


FIG. 4—DESIGN OF ENGINE HAVING ALUMINUM CYLINDER-BLOCK, CYLINDER-HEAD AND OIL-PAN WITH A WET CYLINDER-LINER

The difference in over-all expansion between the head and the cast-iron block seems to give varying degrees of trouble. The sliding of the aluminum head on the gasket has been blamed for water leaks at the cylinder-head gasket. If the head is exceptionally long, it is sometimes advantageous to divide it into two parts, thus cutting the over-all expansion in two. Naturally, the correct way to overcome this difference in expansion is to make the block of the same material as the head. In this day of increased performance and fuel economy, there appears to be a tendency among automotive engineers in general to use the all-aluminum construction.

Keeping Cylinder-Head Studs Tight

The aluminum head is usually held in place by means of steel studs screwed into the cylinder-block. This combination presents a problem that should receive careful attention. As can readily be seen, the aluminum head will expand about two times as much per inch as the bolt. This means that the metal directly under the washer will be subjected to very high compressive-stresses. At the high temperatures common in heads, these compressive stresses may exceed the elastic limit of the aluminum alloy. The result will be a permanent set of the aluminum directly under the washer so that clearance will exist between the aluminum and the washer when the engine cools down. It is common practice to use large washers under the nut to reduce the unit compressive-stresses to a safe value, thereby eliminating any tendency for the nut to loosen. Another way of solving this problem is by the use of bolt material having a high coefficient of expansion. A satisfactory material used commercially at present is aluminum-bronze. The all-aluminum engine previously mentioned was fitted with studs made from this material. It is possible to use high-nickel steel having a satisfactory coefficient of expansion.

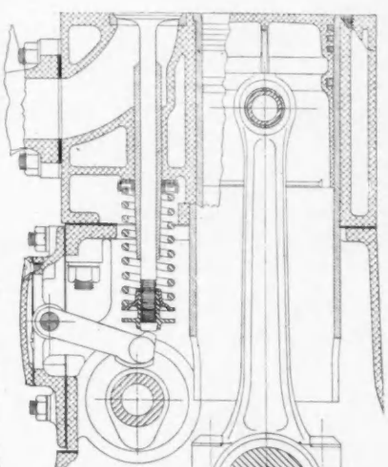


FIG. 5—DESIGN SIMILAR TO FIG. 4, HAVING A DRY LINER

A device has been developed which, when used as a spacer, causes the movement of the washer in contact with the aluminum head to be the same as that of the aluminum surface. This device is shown in place on an engine in Figs. 2, 4 and 5. Briefly, it is a section of 36-per cent-nickel invar tubing of such length that the total expansion of

the tubing and the aluminum directly under the section of tubing will be the same as that of the stud. This condition is possible owing to the fact that the product of the expansion coefficient of steel and the length of the bolt is equal to the product of the expansion coefficient of aluminum and the depth of the aluminum section. As the expansion coefficient of invar is practically zero, the invar acts as a spacer. This general construction may be used in numerous places where expansion is a problem. A very recent application has been the use of the invar spacer in conjunction with compressor pistons of very large size, the piston-rod acting as does the cylinder-head stud described in the foregoing.

Up to the present time, cast iron has retained its place to a large extent as the material for cylinder-blocks. In replacing cast iron with aluminum, for this purpose, it is necessary to use cylinder-liners. It would seem that, in this age of greater efficiency and a desire to reduce transportation costs, the aluminum cylinder-block has some very marked advantages. The weight of the engine will naturally be decreased very materially. Such a reduction will result in greater payloads for the operator of commercial vehicles, and it will mean greater acceleration and better fuel economy for the driver of a passenger car. Other advantages present themselves. Next in importance to reduced engine-weight is the fact that the engine is a better engine from the designer's standpoint. As mentioned before, the aluminum crankcase and oil-pan, as well as rods, pistons, and cylinder-heads, are common to many engines now in use. The design will be improved by the use of aluminum in the major parts of the engine, because one material is used throughout. This naturally allows the most satisfactory use of the Lo-Ex-Ni-Resist-iron combination and results in a very decided improvement over any construction now commonly used.

Mounting of Cylinder Liners

The Ni-Resist iron sleeve may be incorporated in the cylinder design either as a dry sleeve or a wet sleeve. The wet-sleeve construction, shown in Fig. 4, is more advantageous as to thermal considerations. This construction necessitates the use of gaskets both at the top and bottom of the sleeves, but it is considered very desirable from a service standpoint because of the ease of servicing the engine by removing worn sleeves and replacing them with new ones.

The dry-sleeve construction, shown in Fig. 5, eliminates the use of gaskets, but it is slightly less efficient thermally. Both types of sleeve construction are commonly used in the automotive field and have proved satisfactory in service. Each construction has its advantages, and the final design is usually the result of careful study by the individual engineer.

Inserted valve-seats are necessary when using the aluminum cylinder-block and head. It is recommended that aluminum-bronze be used, shrunk in place. Casting these parts in place does not always work out satisfactorily. The high coefficient of expansion eliminates the need of an exceedingly high shrink-fit, and the high thermal conductivity of the bronze tends to reduce the valve temperature.

It is also recommended that either aluminum-bronze or Ni-Resist-iron valve-stem guides be used. With either of these materials the necessity for large valve-stem clearances is eliminated.

So far in this paper an attempt has been made to cover thoroughly the problems and a solution to these problems resulting from the use of materials having different coefficients of expansion in liquid-cooled, automotive engines. The air-cooled engine normally presents the same general problems, only to a more aggravated degree. However, the same general solutions which have already been outlined can be used satisfactorily. Fig. 6 shows a section through an air-cooled engine. It will be noticed that the cylinder is made from aluminum alloy and the piston operates in a liner. The liner is made of Ni-Resist iron and can be either cast or shrunk in place. This construction naturally calls for the use of the Lo-Ex piston.

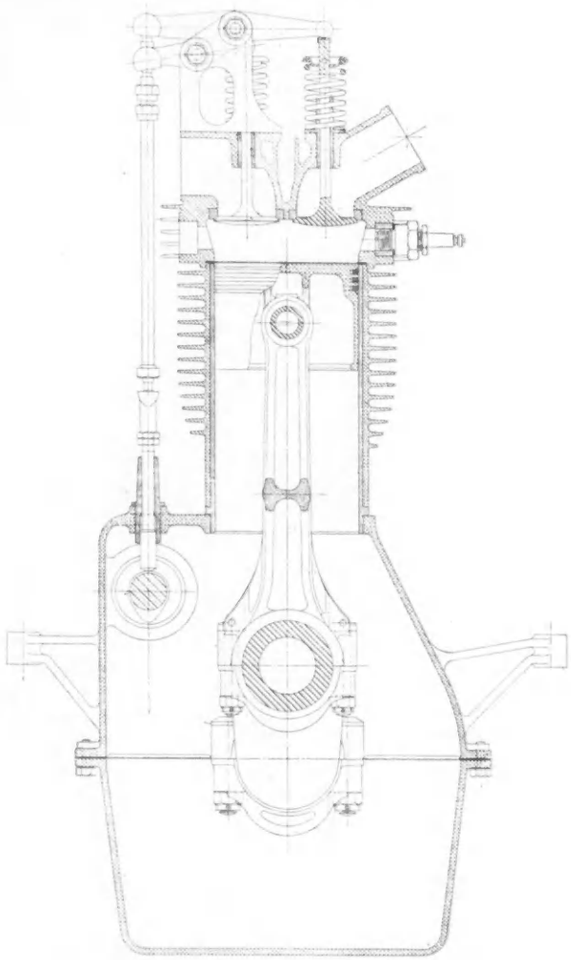


FIG. 6—AIR-COOLED ENGINE HAVING ALUMINUM-ALLOY CYLINDER WITH NI-RESIST-IRON LINER

This particular combination has been tested in air-cooled engines for some time and has been found highly satisfactory. As would be expected, the engine runs cooler than with the cast-iron cylinders which were replaced. To date this combination has not been made to replace forged steel cylinders, because the forging is machined all over and very much thinner sections can be used throughout.

This combination of Lo-Ex and Ni-Resist can be used to very great advantage on the cheaper air-cooled aviation engines which now have cast-iron cylinders, and it also can be used on air-cooled passenger-car engines.

The weight saving possible in an engine using cast-iron cylinders will vary somewhat, but will probably be from 10 to 30 per cent, depending on the design.

Reducing Noise in Aviation Engines

In the aviation field the question of noise is coming to receive a very considerable amount of attention. It is a fact that aluminum pistons cannot be dispensed with in the aircraft engine to advantage. If the piston is to be operated in cylinders made from ordinary materials, large clearances are necessary, causing noises which are becoming more objectionable. The use of other than trunk pistons appears to be out of the question, owing to the type of service. However, the whole problem seems to point to the Lo-Ex-Ni-Resist combination as a solution. Lo-Ex alloy is being used quite extensively in the conventional cylinder, with a decrease of approximately 20 per cent in running clearances as compared with the aluminum-copper piston-alloy. As mentioned previously, this decrease is made possible partly by the lower expansion coefficient and partly by the greater thermal conductivity of the Lo-Ex alloy.

It should be remembered that the ideal engine from an expansion standpoint should be made from one type of material, whether it be aluminum or ferrous alloys. The expansion problems will then, and only then, be at the minimum. In this day of economy and the desire for greater returns on an investment, aluminum has a place in the automotive engine which cannot be filled by other materials. However, for engines of certain types in which weight is not of great importance, aluminum pistons will be used in a cylinder-block made of ordinary cast iron rather than the light-weight aluminum alloys. While both the unconventional type of aluminum piston and the Lo-Ex trunk-type piston have given satisfactory results in ordinary iron cylinders, the designer should be impressed with the possibility of obtaining an even better combination by the use of Lo-Ex alloy pistons and Ni-Resist iron. By simply using a wet sleeve of Ni-Resist iron, the designer may then use a trunk-type aluminum piston which will have life far in excess of any other type used today.

By a satisfactory solution of the expansion problems involved in the design of an automotive engine, the designer may expect from his engines a quality and service life that will be highly satisfactory.

THE DISCUSSION

ARTHUR J. SCAIFE[2]:—How is the cast-iron sleeve shrunk into the aluminum cylinder-block?

FRANK JARDINE:—The cylinder is heated up by almost any available means, we usually use hot water, and the sleeve is dropped in place. The temperature of the cylinder will have to be high enough to increase the size of the bore enough so that the sleeve will slide in place. Usually the sleeve drops in place with no trouble. For production, a guide should be provided to make this a fast operation and to avoid having the sleeve stick on the way down. If it is allowed to stick at any point, the block will cool and the sleeve must be removed by further heating so that the operation will have to be started over again. Removable wet sleeves are made a slip fit in an aluminum block or a free fit in an iron block.

Aeronautic-engine manufacturers heat cylinder-heads and screw the cylinder-barrels in without any trouble. Of course, they are well tooled and do it very quickly.

CHAIRMAN FERDINAND JEHLE[3]:—One of the pistons used to solve the clearance problem was the split-skirt piston. I understand that this design is more or less in disfavor now, because the stresses set up by its flexing are liable to be high. A split-skirt piston made from Lo-Ex alloy would have less expansion, therefore less stress. Would it be better?

MR. JARDINE:—The split-skirt type of piston is not at all in disfavor; we are selling many of them, and we hope to do so for a long time to come. However, we are always looking for ways and means of producing a piston that will run farther and last longer. The No. 132 alloy, Lo-Ex, as we call it, is decidedly better for a piston of any kind, whether it be the controlled type, the spring-skirt type or the trunk type.

L. K. SNELL[4]:—How does the fatigue life of the aluminum compare with that of steel?

MR. JARDINE:—The fatigue life of the aluminum connecting-rod is practically unlimited if it is properly designed. With aluminum, as with all other materials, it is necessary to keep well within the fatigue limits to avoid trouble.

MR. SNELL:—If the aluminum-alloy rod to replace a steel rod is designed for a certain stiffness, with the stresses in proportion to the material, will the fatigue life be as long as that of the steel rod?

MR. JARDINE:—Yes, always. Virtually all of the connecting-rods are designed at our plant on Harvard Avenue, and we insist on sections that will last as long as or longer than the steel rod.

We use a tensile stress of 12,000 lb. per sq. in., which is well within the fatigue limit. The resulting rods are about 40 per cent lighter than the steel rods and are at least their equal in strength and a little stiffer.

Machining Experiences with Aluminum

W. HOWARD[5]:—I should like to ask about the machinability of this Lo-Ex metal?

MR. JARDINE:—The ordinary shop reports it to be just like other aluminum alloys or easier, but we always recommend the use of tungsten-carbide tools for it in production. One well-known manufacturer has been using Lo-Ex for approximately two years now, machining it entirely with tungsten-carbide, with the exception of the piston-pin hole in which he uses a diamond tool for finishing. We find that the diamond gives a bearing that cannot be beaten for roundness, smoothness and uniformity in the size of bore. We think that a diamond should be used for all piston-pin holes, and it is a production necessity for the Lo-Ex alloy. However, experimental parts can be machined without a diamond.

MR. SNELL:—About 10 years ago I worked with Mr.

[2] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.
[3] M.S.A.E.—Research engineer, White Motor Co., Cleveland.
[4] M.S.A.E.—Eaton Axle & Spring Co., Detroit.
[5] M.S.A.E.—Chief inspector, White Motor Co., Cleveland.

Jardine in developing some split-skirt aluminum pistons, and the outstanding thing that I found at that time was that the aluminum piston had to be machined accurately.

I sent a car, the pistons of which were finished to my instructions but in my absence, to the Coast. About two weeks later I received a wire from the Coast saying that the car smoked so that the crew did not dare to drive it on the streets of Seattle; so I had the car shipped back home.

When it arrived I found that, while the experimental-room foreman thought that he had machined the pistons according to my instruction, with about 0.0017 in. end-play in the ring-grooves, the grooves were not straight but were snaky, and the surfaces were not smooth. The rings were of approximately the right width, but they also were snaky.

At that time I was fitting up a car to demonstrate to the dealers, and I personally supervised the fitting of its pistons and rings. I saw to it that the rings and the ring grooves were true, so that the dial indicator stood still when the piston was rotated. The rings were put between two surface-plates and showed about 90-per cent bearing. The rings in the grooves were fitted with 0.001-in. to 0.0015-in. clearance.

That car, with plain rings, did not smoke after being driven 75,000 miles. Those pistons can be taken out today, and a 0.002-in. feeler cannot be inserted between any ring and its groove. These pistons were sand cast from No. 12 aluminum alloy, and the engine was a Knight type.

CHAIRMAN JEHLE:—Is this nickel-alloy cast-iron commercial? Can cylinder-blocks be made from it?

MR. JARDINE:—The Ni-Resist iron, as the International Nickel Co. calls it, is in use in a commercial way, largely for non-corrosive castings, because it does resist corrosion to a certain extent. It has been used a great deal in simple castings of different kinds, but I have never heard of anything in the way of a complicated casting like a cylinder-head or cylinder-block. I believe that the only real obstacle in the way of making such castings is the fact that, like all other new alloys, a certain amount of foundry technique has to be worked out before satisfactory castings can be made.

We had some trouble at first in getting sleeves, but that is very easy after learning how to gate the castings. The International Nickel people intend to make these sleeves by the centrifugal casting process. Cost would be likely to be a greater objection than its casting properties to the use of Ni-Resist iron as a cylinder-block material. The minimum requirements of 12.5 per cent of nickel and 5 per cent of copper in this alloy would make the price considerably higher than that of ordinary cylinder castings.

Growth of Aluminum Alloys

MR. SCAIFE:—Does the Lo-Ex metal grow, shrink or change in shape after it is machined, or is it fairly uniform in production?

MR. JARDINE:—It has so little growth that it can hardly be measured in a casting as it comes from the mold. All pistons are heat-treated castings. If there is a question of excessive growth in an alloy, especially for anything like a piston, which is to be fitted closely, we either use an alloy that will not grow or else we heat-treat it to remove the growth before the casting is shipped to the customer. The heat-treatment which we are using at present on the Lo-Ex alloy removes only part of the growth, but the remainder is so small and gradual that it has never given any trouble.

The average piston, especially in a water-cooled engine, grows very slowly in the skirt. When the heads reach high temperatures, the growth is quite noticeable, but the ordinary alloy in the ordinary conventional engine very seldom shows growth except possibly in the case of a trunk-type piston of say our standard 10-per cent-copper alloy that has been fitted very closely. Many aviation engines are running without trouble today with pistons that have not been, as we say, "de-growthed."

JOHN MCGEORGE[6]:—Is the growth permanent?

MR. JARDINE:—Yes, the growth is permanent.

MR. MCGEORGE:—If the piston is eased up after the growth occurs, will it then be all right?

MR. JARDINE:—Yes, providing it is not done too soon. If a piston should be eased up after sticking during its first day of running, it might still grow a little more. It is a matter of time and temperature.

MR. SNELL:—What is the most approved method now for finishing cylinder-walls for aluminum pistons?

MR. JARDINE:—Almost everyone now hones the cylinder, and I think honing is very much superior to anything else. It is usually quite cheap, but, like all other processes, it is subject to abuses and poor results. However, the average honed cylinder today is quite satisfactory.

Vertical Action Wanted in Honing

One thing should be given more attention in honing. Most manufacturers use a hone that turns very rapidly and goes up and down very slowly. I contend that the hone should work up and down more and not rotate so rapidly, so that all of the lines in the bore will be up and down, as they are after the pistons are run in the cylinder.

Some manufacturers deliberately fit their pistons a little too tight, and the cylinder, being ground and left quite rough, will wear down pistons until they wear in. That makes a very nice job when it is carefully handled, but we think that it is better to get both the cylinder and the piston properly surfaced before they are put together. At least one manufacturer grinds the cylinders and then hones them. That makes a wonderful job, if you can stand the expense.

MR. SNELL:—I believe that I initiated that job. We decided to grind the cylinders to size and then to use a very fine hone to bring them to a polish, without allowing anything for the finish of the hone. I understand that this process is being used still. We found that if the grinder chattered or if anything happened to the grinder that interfered with producing a true cylinder, the hone would show every chatter mark, and corrections could be made on the grinder.

MR. JARDINE:—As I remember it, that particular hone made about 110 up-and-down strokes per minute and about 3 r.p.m. The hones were spaced equally, and they moved unequally between strokes, so that any individual coarse particle in the stone would never come back again in the same line and make a groove.

MR. MCGEORGE:—Can cylinders be honed so that pistons do not need to be fitted?

MR. JARDINE:—I have seen some very nicely honed cylinders, the manufacturer of which fitted the pistons

[6] M.S.A.E.—Consulting engineer, Cleveland.

selectively with a clearance tolerance of about 0.002 in., but we do not think there is profitably any way of eliminating the fitting of pistons if, as most manufacturers insist, the tolerance is to be held within 0.001 in. Extremely close inspection would be required, and the machine work would have to be very close to keep within that limit.

MR. MCGEORGE:—What limits are used?

MR. JARDINE:—On some cylinders the standard limit is plus or minus 0.001 in. Some have a limit of plus or minus 0.0005, and some have plus 0.000 and minus 0.001 in. The piston tolerance usually is plus 0.001 or minus 0.000 in. or plus 0.000 or minus 0.001 in.

MR. MCGEORGE:—How nearly parallel must the sides be?

MR. JARDINE:—They must come within 0.001 in. of being parallel.

MR. MCGEORGE:—Are they large at the ends?

MR. JARDINE:—We find pistons come large at the ends in some shops and large in the middle in others. It is hard to tell how they will come; it depends entirely on the machine hands and the machine setup.

QUESTION:—How does the price of this new alloy compare with that of other alloys?

MR. JARDINE:—It is slightly lower than that of the conventional 10-per cent copper alloy.

MR. MCGEORGE:—How does the finish in a honed cylinder compare with a carefully bored diamond-tool finish?

MR. JARDINE:—I do not know that I have ever seen a cylinder that was bored with a diamond tool. I imagine that it should be very nice, but the process would be rather expensive because the ordinary commercial diamond costs something like $75, and it would most likely be torn out and probably lost if it should strike a hard spot. Then when the diamond becomes dull it will cost from $5 to $10 to get it sharpened. If honing is done correctly, I think no one could want anything better.

Automobile Engine Acceleration

(*Concluded from p.* 278)

done, but I think some very interesting results could be obtained. In fact, most of the effect on acceleration is on the inside surface of the manifold. In that connection I should like to say that the same effect on the acceleration can be obtained by adding heat, increasing the accelerating charge or increasing the volatility of the fuel. That is, as we increase the acceleration at low speeds, unless we are very accurate in a small range, the mixture will become too rich at the higher speeds, which is what I was trying to point out in the chart, where the acceleration rate decreased at the higher speeds.

CHAIRMAN B. B. BACHMAN[18]:—The work on engine acceleration has covered considerable time and is an excellent example of the service that has been rendered to the industry and these organizations by the staff of the Bureau of Standards. I believe that this work was originally started in 1920, but I had not realized that it was so long ago, although I knew that it was some time. A number of men have been engaged in the work and they have all done a fine job. The subject is full of instruction, probably too much to be picked up at one sitting. I know that we will all look forward to the publication of this work in its present completed form. I hesitate to use the word completed because each time we think we have just about arrived at a stopping place in these investigations, some new development comes up that lets us take a few steps farther forward.

[18] M.S.A.E.—Vice-president in charge of engineering, Autocar Co., Ardmore, Pa.

The Packard Diesel Aircraft Engine

(*Concluded from p.* 281)

the fact that the elasticity of a pipe and its contained fuel can be important aids in securing that extremely abrupt beginning and ending of injection which is so desirable. Perhaps this very simplicity may thus have had a part in necessitating the high maximum pressures, because fuel inefficiently sprayed must be injected early to burn clean.

In comparing the four-stroke Packard with the two-stroke Junkers, I am again strongly impressed with the advantages of two-stroke operation. That the Packard can show a fuel-consumption rate any lower than that credited to Junkers, while the brake mean effective pressure is about the same, is improbable. The maximum pressure of the Junkers is not given but is most certainly no higher than in the Packard. We therefore have the direct evidence of that doubling of power output per cylinder which has been the objective of two-stroke workers. This can only mean that future development will be directed more toward the two-stroke Diesel, especially in the very large engines for main-line air-transport service and that we may soon expect to have two-stroke engines which are considerably lighter than is possible with four-stroke operation. This comparison has been discussed more completely by E. T. Vincent and myself in a paper entitled The Aircraft Diesel Engine[6], which was read before a meeting of the American Society of Mechanical Engineers that was held at St. Louis in May, 1929.

[6] See *Aeronautical Engineering*, January-March, 1930, paper AER-52-5.

Motor-Vehicle Legislation *and* Taxation

By Pierre Schon[1]

Annual Meeting Paper Illustrated with Chart and Diagrams

A MOST serious problem that now confronts designing engineers, truck manufacturers and operators, which becomes more intricate every year, is the wide range of State rulings and legal restrictions concerning sizes, weights and taxation of commercial motor-vehicles. Several instances of typical bills presented to legislatures are given by the author, who then discourses on the interference with long-distance hauling that this wide variety of regulations causes. He then comments upon the differences in State laws which handicap motor-truck design, and gives statistics on the maximum limits on width, height and length of motor-vehicles with analyses of their merits.

Concerning the weight restrictions on commercial vehicles, the weight regulations as set up in the Hoover Code are tabulated and the inconsistencies of the Model Act are analyzed. The author says that present regulations and restrictions on commercial-vehicle weights may be practical for solid tires and that possibly some highway engineers have good reasons to recommend that commercial motor-vehicle weights should be reduced below the present limit to protect gravel roads in their States; but, from tests made by the Bureau of Public Roads in connection with the Society of Automotive Engineers and the Rubber Association of America, conclusive evidence is available that pneumatic tires cannot cause any serious damage to well-constructed pavements. He then shows the results of tests conducted for a period of years beginning in 1923 at the experimental station of the Bureau of Public Roads at Arlington, Va., and analyzes the most important results obtained from these scientifically conducted tests.

On the subject of taxation, the author says that commercial transportation is subject also to attacks which originate from excessively high license-tax fees and the constantly increasing rate of the gasoline tax. Prohibitive taxation is a serious handicap to any industry or business, and excessive taxation creates a handicap on small and large-scale operators as well, according to the author. In addition to the excessive taxation in their home State, interstate operators are forced in many cases to pay double or even triple taxes.

As to the tax on gasoline, this ranged from 2 to 6 cents per gal. in most of the States during 1929; only three States did not levy this tax, but the legislators in those States during 1929 enacted laws providing for the collection of a gasoline tax during 1930. The author enumerates some good reasons why operators of commercial vehicles should give support to a reasonable tax on gasoline.

In conclusion, an example is presented of how a well-organized State-organization succeeded during 1929 in killing a proposed amendment to State laws in New Jersey and saved truck operators from an increase of 100 per cent in license-tax fees.

In the discussion, J. F. Winchester comments upon the successful results obtained by the Motor-Truck Club of New Jersey, especially in regard to the good effect this work has had in the formulation of liberal laws. In his opinion, manufacturers' representatives should constantly devote very careful thought and make very capable analyses of the various factors that cause adverse legislation. He said further that he can see no logical reason why the gross weight on pneumatic tires should not be considered beyond the range indicated by Mr. Schon. He also comments upon the tax on gasoline and the subject of collecting this tax.

The subject of proper spacing of axles is discussed and the matter of whether the Society should standardize on loading-space dimensions is brought up, but it is stated that it is not desirable that the Society should actively favor or oppose legislation. The remark is made that detailed requirements are sometimes enacted into statute law, after which it is very difficult or impossible to change them. Other subjects include the recommendation that the Society try to do its part to correct detrimental legislation matters in a way that will not involve the Society in entangling alliances or result in adverse criticism. Interstate travel with trailer combinations, tire equipment and modes of procedure are also discussed.

ONE of the most serious problems confronting designing engineers, truck manufacturers and operators during the past, and one which becomes more intricate every year, is the wide range of State rulings and legal restrictions concerning sizes, weights and taxation of commercial motor-vehicles. During 1929, over 2500 amendments were presented to the legislatures of 41 States, which were in session last year, affecting the design, manufacture and operation of motor-vehicles.

It has been customary in the past for certain selfish interests to support amendments to existing rules and new regulations intended to handicap the economical operation of motor-trucks and motorcoaches. Legislation of this type was in many instances directed against both motorcoaches and trucks, and obstacles were created in various ways. Restrictions on size, weight and speed of motor-vehicles below practical limits, interfering with their economical operation or, in some cases, excessive taxation, were enacted to prevent motorcoaches or trucks from entering competitive fields. However, it is gratifying to know that, during recent years, a broader vision of the transportation field in general is gradually welding the various transportation methods into a closer unit of coordination, and it is apparent that former opponents to motor transportation will eventually become large users of both trucks and motorcoaches. This is evidenced by the fact that rail-

[1] M.S.A.E.—Sales engineer, General Motors Truck Co., Pontiac, Mich.

roads are now operating over 10,000 motorcoaches and trucks; and, during 1929, transportation by airplane has been coordinated with transportation of passengers by rail. Other interests also have taken it upon themselves to change existing rulings and submit bills with amendments for new or more severe regulations of motor-vehicles.

Typical Bills Presented

Among the large number of bills affecting motor-vehicles presented to the various legislatures during 1929, a few have been selected to serve as typical exhibits.

During the 1929 session of the Michigan Legislature, a representative from Upper Michigan submitted a bill in Lansing to reduce the height of motor-vehicles. Upon investigation it was found that a furniture truck, with a bed spring fastened onto the rear end of the body and sticking up in the air, passed his home one evening and tore down his telephone wire. So this representative submitted a bill to reduce the height of motor-vehicles in Michigan.

In New Jersey, a bill was submitted to increase license fees 100 per cent on all motor-trucks.

In California, a bill was submitted forcing every motor-vehicle to be equipped with an ash tray to collect cigarette butts.

In Missouri, a bill was presented to prohibit the use of trailers.

In Illinois, a measure was submitted to force truck operators from other States entering Illinois to pay the regular Illinois State license fees.

The legislature of a Western State debated a bill supported by the Painters' Union to prohibit the use of spray guns for painting motor-vehicles.

In Michigan, a number of bills were presented to the legislature in March, 1929, attacking the operation of motor-trucks from three different angles: (*a*) reductions in height, length and weight; (*b*) higher license fees and (*c*) a higher gasoline tax. Measure (*a*) affected the earning capacity of commercial vehicles; measures (*b*) and (*c*) would have increased the operating cost per mile. If any one of these bills had succeeded in passing, operators would have been forced to increase freight rates or absorb these extra burdens in their profit-and-loss statement.

Interference with Long-Distance Hauling

The wide variety of regulations controlling sizes and weights of commercial vehicles is one of the greatest handicaps interfering with the expansion of interstate transportation. In a conference with 25 General Motors Export Co. transportation engineers from overseas, it was pointed out by some of them that it is very difficult to promote long-distance hauling by motor-truck in foreign countries due to the frontiers and the national boundaries between those countries.

In the United States, we have free interchange of commerce between the various States, and there are no restrictions placed on the movement of merchandise from one State into another. Occasionally, it happens that temporary boundary lines are set up to prevent the spreading of diseases and pests, such as the hoof-and-mouth disease, the corn borer and the Mediterranean fly. Interstate transportation by motor-truck and motorcoach, however, one of the most important essentials of our civilization, is crippled by permanent restrictions in the free movement from one State into another; in other words, imaginary boundary lines have been erected between our various States that hinder the free movement of vehicles used for interstate commercial transportation. This condition has developed without any intent on the part of our National Government or the State legislatures to put obstacles in the way of motor-vehicle operation, but it is merely a result of lack of cooperation between manufacturers and operators to safeguard their interests. Spasmodic efforts in fighting a bad bill when conditions become critical are not sufficient to safeguard the progress of commercial transportation.

Tabulations, giving the maximum dimensions and weights allowed by law in the 48 States and the District of Columbia, reveal the interesting fact that only in two adjacent States could be found a similarity in regulations, namely: California and Arizona. During the 1929 session of the legislature, California reduced the maximum axle-weight from 18,000 to 17,000 lb., while Arizona retained the 18,000-lb. limit. This action on the part of the California legislature eliminated the only example of two neighboring States having the same regulations.

In our Central States, with highly developed interstate commercial transportation, a motor-truck loaded to the limit of the Indiana and Kentucky laws, allowing a 28,000-lb. gross vehicle-weight, cannot be driven into any of the adjacent States, as Illinois and Ohio allow only a 24,000-lb. gross load. Michigan allows an 18,000-lb. gross axle-weight, forcing the operators to load 10,000 lb. on the front axle to enter the State of Michigan. When entering the State of Kentucky, it is found that the 96-in. width allowed in the States of Indiana, Michigan, Illinois and Ohio, exceeds the legal 90-in. width in Kentucky by 6 in.

When it comes to dimensions of length, vehicles permitted in Illinois, Michigan, Pennsylvania, Indiana and Kentucky, for instance, cannot enter the State of Ohio, due to the 30-ft. length-restriction in Ohio, while the surrounding States allow greater length for single vehicles.

A case is pending in the United States District Court at Toledo in which a long-distance operator from Michigan, as defendant, is trying to protect an investment of $100,000 in vehicles which are longer than 30 ft. and which have been in operation for several years through the State of Ohio; but, recently, several Ohio county officials have decided to enforce the 30-ft. ruling and prevent this operator from passing through Ohio.

Many motorcoaches are operating in Ohio today where the operators are actually at the mercy of county officials because the vehicles exceed the 30-ft. legal-length limit.

In another case, operation of a fleet of specially built vehicles had to be discontinued in the State of Connecticut, due to a sudden and unexpected ruling reducing the permissible over-all length of a vehicle from 40 to 33 ft. Another example of sudden change in regulatory restrictions, which caused a severe financial loss to an operator due to reduction in the over-all combination length from 85 to 75 ft., was enacted in Minnesota during 1929.

Operators are subject to attacks from various angles, and a variety of restrictions may be made into laws by any one State, thus causing premature obsolescence of commercial vehicles aggregating millions of dollars. Operators in some States are unable to plan their replacements and additions of new vehicles, due to the uncertainty as to how possible changes in legal restric-

tions may affect those vehicles purchased today within a period of one or two years, or five years, the profitable service-life of a motor-truck.

Laws Handicap Motor-Truck Design

The problems of the designing engineer and the manufacturer are multiplied when attempts are made to incorporate into a certain heavy-duty motor-truck design all factors required to permit the finished product to be used under the 49 different varieties of State laws. This situation becomes even more complicated when the many different speed-regulations are taken into consideration. With the modern type of brake design and the application of vacuum or compressed-air booster-brakes, the operation of pneumatic-tired trucks is comparatively safer than is that of passenger-cars. This was brought out recently by statistics compiled in the State of Massachusetts where the percentage of accidents with motor-trucks was considerably lower than with passenger-cars.

Speed regulations in most States are antiquated in relation to the improvements which have been made in the safety features controlling the operation of commercial vehicles. Designing engineers are constantly searching for improvements to reduce the cost of operation and incorporate greater operating efficiency in the design, but these efforts are handicapped by impractical legal restrictions.

The manufacturer of a heavy-duty vehicle is restricted by law, in many cases, to a limited market for the vehicle in certain States, because a vehicle which may comply with the regulations and rulings in one State cannot be legally operated in other States. Unless the efforts of manufacturers' and operators' associations are coordinated in the future, there is very little relief in sight from the present situation. This question has been discussed pro and con for many years, but no satisfactory results have been obtained so far in formulating State legislation along sane and practical lines of procedure.

The Motor-Vehicle Conference Committee of the National Automobile Chamber of Commerce has done considerable work along this line and has been very active for a number of years in promoting the idea of uniform motor-vehicle legislation. The National Conference on Street and Highway Safety, under the able leadership of Secretary Hoover as chairman, formulated a Model Act known as the Hoover Code during 1926. One part of this Code is entitled: "Uniform Act Regulating the Operation of Vehicles on Highways." The so-called Hoover Code is basically sound and it can be recommended as the best effort yet put forth to obtain greater uniformity of legal rulings and restrictions.

TABLE 1—MAXIMUM HEIGHT, WIDTH AND LENGTH ALLOWED BY STATES FOR COMMERCIAL VEHICLES

Height[2]			Width[3]		Length			
					Single Vehicles[4]		Combination of Vehicles[5]	
No. of States	Ft.	In.	No. of States	In.	No. of States	Ft.	No. of States	Ft.
2[7]	None	..	5	None	23	None	22	None
4	12	..	1	14	2	28	1	40
1	12	2	6	90	9	30	1	50
12	12	6	1	93	11	33	5	60
1	13	6	34	96	2	35	2	65
1	14	..	2	102	2	40	1	75
8	14	6	..	..	..	..	17	85

[2] The Hoover Code and the N.A.C.C. recommend 14 ft. 6 in.; Missouri allows 12 ft. 6 in. in the country and 15 ft. in the larger cities.

[3] The Hoover Code and the N.A.C.C. recommend 96 in.; Connecticut allows 102 in., but only 96 in. for public carriers; Missouri allows 96 in. in the country, but 108 in. in cities; California allows 100 in. for vehicles with dual-pneumatic rear-tires.

[4] The Hoover Code and the N.A.C.C. recommend 33 ft.; Connecticut reduced from 40 to 33 ft. during 1929; the recommendations in the Motor-Vehicle Code call for a maximum length of 40 ft.

[5] The Hoover Code and the N.A.C.C. recommend 85 ft.; Minnesota reduced the allowance from 85 to 75 ft. during 1929.

TABLE 2—STATE HIGHWAY CLASSIFICATION OF ROADS BY HIGHWAY ENGINEERS AS TO MAXIMUM-WEIGHT REGULATIONS FOR EACH TYPE OF ROADBED; FROM THE HOOVER CODE[6]

Classification of Highways	Type	Class *A* Weight, Lb.	Class *B* Weight, Lb.	Class *C* Weight, Lb.	Class *D* Weight, Lb.
Uniform Vehicle Code, Aug. 20, 1926, City of Washington, National Conference on Street and Highway Safety, Hon. Herbert Hoover, Secretary of Commerce, Chairman	Four-Wheel Vehicle	32,000	26,000	21,000	16,000
	Four-Wheel Truck, Maximum Axle Weight	25,600	20,800	16,800	12,800
	Maximum Axle Weight for Trailers	16,000	13,000	10,500	8,000
	Maximum Axle Weight if less than 8 ft. apart	12,800	10,400	8,400	6,400
	Maximum Vehicle Weight for Six-Wheel Truck	38,400	31,200	25,200	19,200
	Maximum Axle Weight for Six-Wheel Truck	16,000	13,000	10,500	8,000
	Maximum Weight per Inch Width of Tire	800	800	800	800

[6] These recommended weights were revised at the Safety Conference in the City of Washington during the week of May 25, 1930.

Maximum Limits on Width, Height and Length

Table 1 shows maximum limits on the width, height and length of motor-vehicles allowed by States. These figures show a wide variety of legal restrictions governing the size of vehicles. It may be interesting to call attention to the fact that telephone companies in some States are not legally allowed to transport poles over State highways, as the length of the poles in most cases exceeds the maximum length allowed by the State laws for either single-vehicle length or length of vehicles when combined. (See Figs. 1 to 4.)

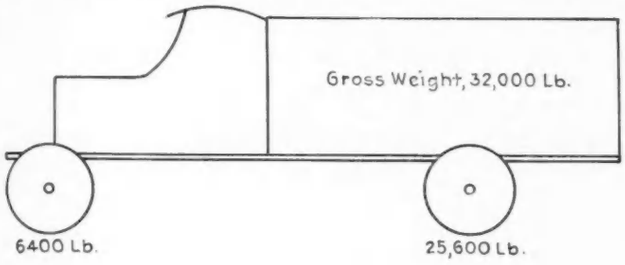
Weight of Commercial Vehicles

One of the most constructive things in the Hoover Code is the classification of highways according to the carrying ability of the pavement. In this Model Act, it is left to the discretion of the State highway-engineers to classify roads as *A*, *B*, *C* and *D*, with maximum-weight regulation for each type of roadbed; see Table 2.

In some States, restrictions on gross vehicle-weights or per axle are based on protecting the poorest highways in the State and, under this method, the public is prevented from utilizing the carrying ability of the better roads in those States. Leading out of Detroit, for instance, several highways having an 8 to 10-in. concrete-base are capable of carrying maximum loads without injury to the roadbed during the entire year. Less than a year ago, during the 1929 session of the Michi-

gan legislature, a bill was presented by one of the members in the House to reduce the gross axle-weight limit from 18,000 to 14,000 lb. to protect the gravel roads in the upper part of Michigan. If the passage of this bill had been successful, operators of heavy-duty trucks and trailers in the State of Michigan would have been forced to face a loss of millions of dollars in oversize equipment that would have been obsoleted, and a reduction in earning capacity of each vehicle by 4000 to 8000 lb. of payload capacity per trip.

Under the Hoover Code classification of highways, operators of heavy-duty trucks could determine definitely the type of equipment needed for certain routes, without fear of having outlaw equipment on hand in six months or a year from the date of purchase. The State Highway Department, in laying out and building new roads, would be able to determine the type of pavement required for the various districts. For territories



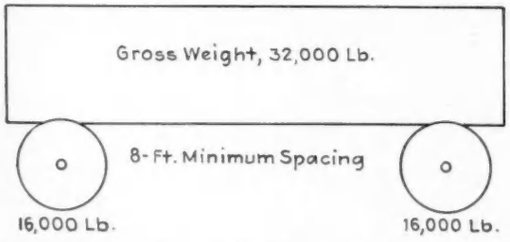


FIG. 1—COMPARATIVE WEIGHTS OF FOUR-WHEEL VEHICLES AS RECOMMENDED IN UNIFORM VEHICLE CODE DATED AUG. 20, 1926

where no heavy trucking is done, Class-*C* or Class-*D* roads would be sufficient to take care of country traffic; whereas, in the industrial sections, Class-*A* highways would provide roads of maximum carrying-capacity, assuring economical movement of heavy tonnage.

Class-*C* and Class-*D* roads would be protected from being damaged by heavy-duty vehicles and the general public would benefit by lower freight-rates and more efficient service if operators were permitted to take full advantage of the maximum carrying ability of Class-*A* highways. Economies in the building of new roads would be effected if highway engineers were able to predetermine the necessary strength of the roadbed and bridges under a method of classifications as set up in the Hoover Code, and therefrom lay out a program specifying where traffic demands a Class-*A* or a Class-*D* pavement.

Hoover Code Protects Transportation

The Hoover Code as formulated in 1926 is one of the most constructive pieces of work which has been done

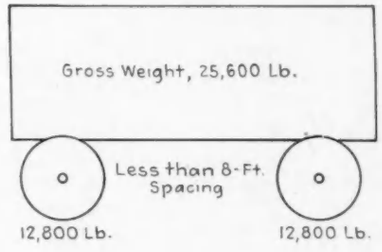
TABLE 3—MAXIMUM GROSS WEIGHTS ALLOWED BY DIFFERENT STATES

Four-Wheel Vehicle [7]		Per Axle on Four-Wheel Vehicle [8]		Six-Wheel Truck [9]		Per Axle on Six-Wheel Truck [10]		Per Wheel [11]		Per Inch Width of Tire [12]	
No. of States	Lb.	No. of States	Lb.	No. of States	Lb.	No. of States	Lb.	No. of States	Lb.	No. of States	Lb.
8	None	24	None	37	None	39	None	40	None	9	None
2	16,000	1	14,400	1	27,500	1	8,000	1	6,000	1	500
10	20,000	2	15,000	1	30,000	1	8,500	1	7,000	12	600
5	22,000	6	16,000	2	34,000	1	11,000	1	7,500	1	625
2	23,000	1	17,000	2	36,000	1	11,200	2	8,000	5	650
4	24,000	1	17,600	1	38,000	1	14,000	3	9,000	8	700
3	25,000	6	18,000	1	38,400	3	16,000	1	11,200	1	750
2	26,000	1	18,500	4	40,000	2	18,000	..	.....	12	800
9	28,000	1	18,800	..	.....	..	.....	..	.....	..	.....
1	30,000	1	19,500	..	.....	..	.....	..	.....	..	.....
1	32,000	4	22,400	..	.....	..	.....	..	.....	..	.....
2	12,000 (Payload)	1	25,000	..	.....	..	.....	..	.....	..	.....

[7] The Hoover Code of 1926 recommends 32,000 lb. and the N.A.C.C., in 1929, recommends 28,000 lb.
[8] The Hoover Code of 1926 recommends 25,600 lb., and the N.A.C.C., in 1929, recommends 22,400 lb.
[9] The Hoover Code of 1926 recommends 38,400 lb., and the N.A.C.C. gives no figures for 1929.
[10] The Hoover Code of 1926 recommends 16,000 lb., and the N.A.C.C. gives no figures for 1929.
[11] The Hoover Code of 1926 and the N.A.C.C. report of 1929 give no figures.
[12] The Hoover Code of 1926 recommends 800 lb., and the N.A.C.C. report of 1929 recommends 400 to 800 lb.

to protect the interest of commercial transportation; but at that time the solid tire was still a factor and the rapid growth of pneumatic-tire applications could not be foreseen. Therefore, the Model Act had to be set up to meet existing conditions as of 1926. With more pounds of payload for each pound of dead weight, made possible with modern high-speed vehicles on balloon tires, it is felt that the time has arrived for considering certain changes in the recommended weight regulations as set up in the Model Act, so that these regulations may conform to the needs of today and the needs of the future. The weight regulations as set up in the Hoover Code are shown in Table 3, in a condensed form, and are illustrated in Figs. 1 and 2.

The weight regulations as originally set up in the



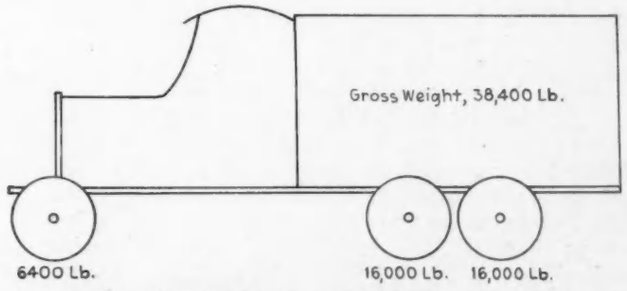


FIG. 2—INCONSISTENCY IN THE MODEL ACT REGARDING WEIGHT REGULATIONS

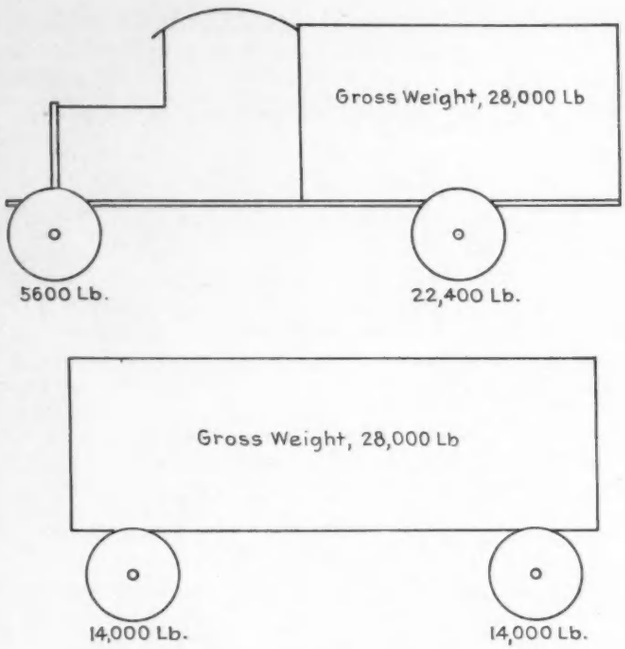


FIG. 3—REVISION OF GROSS-VEHICLE-WEIGHT FIGURES; N.A.C.C. MOTOR-VEHICLE CONFERENCE COMMITTEE RECOMMENDATIONS

Model Act have met with considerable objection on the part of legislators, highway engineers, trailer manufacturers and operators. Axle weights are considered excessive and, in the allowable gross vehicle-weights, no distinction is made between a four-wheel truck and a four-wheel trailer. Both of these vehicles may have the same number of axles or wheels, but the carrying capacity and load distribution are entirely different. In a heavy-duty motor-truck of conventional design, the strength of the rear axle is calculated to carry from 70 to 80 per cent of the gross weight, while the front axle only carries from 20 to 30 per cent. (See Fig. 1.)

With balloon-tire equipment, the load distribution is gradually being standardized to distribute the load per tire more evenly. For a four-wheel truck, one-third of the gross vehicle-weight is on the front axle and two-thirds on the rear axle when equipped with dual tires. For a six-wheel truck, one-fifth is on the front axle and four-fifths on the rear tandem-axles when equipped with dual tires. For a four-wheel trailer, one-half is on the front axle and one-half on the rear axle. For a six-wheel trailer, one-third is on the front axle and two-thirds on the rear tandem-axle.

The steering mechanism on the motor-truck, being incorporated in the front axle, prevents the axle from being loaded as heavily as the rear axle; lighter load on the front axle also provides for easier steering. Rear wheels on a motor-truck can be equipped with dual tires, but this cannot be done with front wheels, as it would seriously interfere with the steering action. In a four-wheel trailer we have an entirely different condition, as the two axles are generally of the same carrying-capacity; therefore, the design of a four-wheel trailer lends itself to a 50-50 load-distribution on the two axles. As manual steering is being replaced by a tow bar, a 50-50 weight distribution is entirely practicable and commendable so as to use the same type of tire equipment on both axles.

It will be noted in Fig. 1 that the Model Act provides for a maximum gross axle-weight for the four-wheel truck of 25,600 lb., and that the gross limit for the vehicle itself is only 32,000 lb. This leaves a weight of 6400 lb. for the front axle, a load distribution suitable for solid tires but not suitable for pneumatic tires. It will also be noted that maximum axle-weight for a four-wheel trailer is given as 16,000 lb., which equals on two axles the maximum gross vehicle-weight of 32,000 lb. This difference in axle-weight figures for two vehicles is inconsistent for the reason that the weight on the trailer axle cannot be more injurious to the pavement than the weight of a truck axle. Many States have no gross vehicle-weight limitations, basing their rulings solely on axle weights, wheel weights, or weight per inch width of tire.

Rulings on axle spacings are also in effect in some States and this is a very practical method of controlling vehicles from damaging the pavement or bridges by excessive weights over a concentrated limited distance.

Another inconsistency is found in the Model Act under weight regulations, setting a limit of 12,800 lb. on each axle if spaced less than 8 ft. apart, while, under the ruling governing the axle weight of a six-wheeler, a gross axle-weight of 16,000 lb. is permissible. (See Fig. 2.) In a six-wheeler it is not practical to have a greater spacing between the two rear axles than 54 in. It is therefore reasonable to ask the question, "If axles, spaced less than 8 ft. apart, can carry only 12,800 lb.

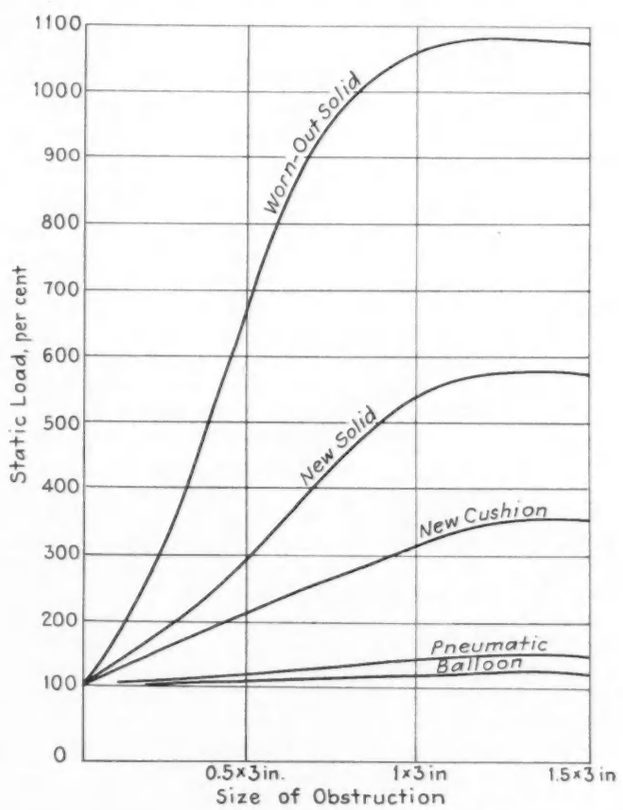


FIG. 4—IMPACT ON PAVEMENT AFTER PASSING OVER OBSTRUCTIONS OF VARIOUS HEIGHTS WITH A 2-TON TRUCK AT A SPEED OF 12 M.P.H.

gross weight per axle, why can a six-wheeler, where it is not practical, nor possible, to have a greater spacing between the two rear axles than 4½ ft., weigh 16,000 lb., gross, per axle?"

Subsequent to the formulation of the uniform vehicle code, the Motor-Vehicle Conference Committee revised the 1926 gross-vehicle-weight figures from 32,000 lb. to 28,000 lb. for a four-wheel vehicle, with a maximum weight per axle limited to 22,400 lb. (See Fig. 3.) A scale of weights, per inch width of tire, was also set up by the Motor-Vehicle Conference Committee, in the form of a recommendation, and these figures are based on the carrying capacity of solid tires.

Maximum weights, as recommended in the 1929 and 1930 editions of State Restrictions issued by the Motor-Vehicle Conference Committee, are even more inconsistent than the recommendations made in the Model Act of 1926.

Pneumatic versus Solid Tires

Present regulations and restrictions on commercial-vehicle weights may be practical for solid tires and highway engineers have good reasons to recommend that commercial motor-vehicle weights should be reduced below the present limit to protect gravel roads in their States; but, from tests made by the Bureau of Public Roads in connection with the Society of Automotive Engineers and the Rubber Association of America, conclusive evidence is available that pneumatic tires cannot cause any serious damage to well-constructed pavements. Fig. 4 shows the result of tests conducted over a period of years, starting in 1923 at the experimental station of the Bureau of Public Roads at Arlington, Va. Motor-trucks were tested for shock or impact reaction on the pavement, the trucks being equipped with various types of tire and driven over obstructions of different heights at various speeds. The object of these tests was to determine the stresses induced in the road surface. Special instruments were developed to measure maximum impact-force with sufficient accuracy to meet the needs of obtaining adequate information.

Fig. 4 illustrates one of the most important results obtained from these scientifically conducted tests. It will be noted that the shock on the pavement is negligible with high-pressure pneumatic tires and even less when tires are under-inflated, the condition we have in the new type of truck or motorcoach balloon tire. On the other hand, a glance at Fig. 4 clearly shows that the impact reaction with worn-out solid tires may, under certain conditions, register over 10 times the static load. In other words, the shock on the pavement with a 10,000-lb. axle-weight may register a shock of 15,000 lb. on the pavement with pneumatic tires; while the shock with worn-out solid tires may register more than 10 times the static load, or over 100,000 lb.

The tests in Fig. 4 also proved conclusively that the highest impact-reaction is obtained at a critical-speed period of between 12 and 15 m.p.h. One of the most striking results of these tests shows that, for various tires, the percentage of increase in static load to the capacity is less as the load was increased. This phenomenon probably was due to the closer adherence of the truck wheel to the road under heavy load and also to the enforced cushioning of a greater part of the impact by the tires.

[13] See *Public Roads*, October, 1925.

TABLE 4—PRACTICAL WEIGHT REGULATIONS FOR VEHICLES EQUIPPED WITH PNEUMATIC TIRES[14]

Authority Submitted by a Member of the S.A.E. Transportation Committee	Maximum Weight	Highway Class *A*, Lb.	Class *B*, Lb.	Class *C*, Lb.	Class *D*, Lb.
	Per Axle if spaced more than 8 ft. apart	22,500	19,000	15,500	12,000
	Per Axle if spaced less than 8 ft. apart	17,000	14,000	11,000	8,000
	Per Inch Width of Tire	700	625	550	475

[14] Note a 20 per cent less weight per axle on *solid tires*.

Tests were also conducted with six-wheel trucks and reported in an article entitled, Six-Wheel Trucks and the Pavement[15]. These tests showed that the stresses in a concrete pavement caused by a four-wheel truck are approximately twice as great as those caused by a six-wheel truck carrying the same load.

The propaganda that has been spread in the past that motor-trucks are tearing roads to pieces has caused a very unfavorable reaction against commercial motor-vehicles in many quarters, and the time has arrived when our entire industry, manufacturers and operators, are finding themselves with backs against the wall fighting for their very existence in protecting the transportation of passengers as well as heavy tonnage of merchandise against legislation which, in some cases, may be called confiscatory.

Education Needed To Offset Propaganda

With the solid tires fast passing out of existence, educational work, proving that pneumatic tires do not injure the roads, is necessary to offset the results of past propaganda against commercial vehicles. After careful study of this subject with a number of experienced transportation men affiliated with the motor-truck and the trailer industry, manufacturers, private operators, public carriers and highway engineers, we submit, in Table 4, a recommended scale of weight-regulations in which maximum vehicle-weights have been eliminated and gross axle-weight limitations are based on axle spacings and weights per inch of tire only. This recommended schedule is based on the classification of highways as set up in the Hoover Code, according to the carrying capacity of the pavement, taking into consideration the difference in design of commercial vehicles, difference in load distribution on truck versus trailer axles, carrying capacity of pneumatic tires and the need for uniform weight-regulations.

To carry out the plan of classifying highways according to the carrying capacity of the pavement, it seems commendable that some Federal Government Agency, such as the Bureau of Public Roads, the Department of Agriculture, or the United States Army Engineers, should be assigned to supervise the classification of all highways. The Model Act, as formulated in 1926, is basically sound and, with a few slight amendments to adapt it better to modern needs for the present as well as the future, undivided support should be given to the Hoover Code by every organization interested in the development of commercial transportation.

As previously stated, commercial transportation is subject to attacks by State legislation from three dif-

ferent angles. The first has been discussed, namely, the reduction in earning capacity of motor-vehicles due to unreasonable and impractical regulations controlling their size, gross weight and speed. Attacks from the other two angles originate from excessively high license-tax fees and from the constantly increasing rate of the gasoline tax.

Taxation of Motor-Vehicles

Regarding excessive license fees in a number of States today, economical transportation of heavy tonnage is impossible due to excessive taxation of the type of vehicle needed to operate at a profitable basis of cost per ton-mile. Prohibitive taxation is a serious handicap to any industry or business. Excessive taxation creates a handicap on small and large-scale operators as well. In some instances where hundreds of trucks or motorcoaches are operated by one company, the amount which has to be withdrawn from the business at the start of the year to buy new license plates may run into staggering figures of several hundred thousand dollars. In addition to this excessive taxation in their home State, interstate operators are forced in many cases to pay double and even triple taxes, as one vehicle may be forced to carry license plates purchased in three or more different States. Double taxation is one of the great handicaps to the expansion of interstate operation of commercial vehicles.

The fast-growing use of pneumatic and balloon tires on motor-trucks has made long-distance operation practical and, in those territories where its growth has not been stifled by legal restrictions, long-distance motor-transport has become a matter of public convenience and necessity. Motor-truck freight lines are serving hundreds of towns in territories where service by steam or electric railroad is inadequate or not available. In some cases natural resources cannot be developed except by motor transportation, yet legal restrictions and exorbitant taxes on the types of vehicle required to move available tonnage economically prevent the development of such territories. In some States it seems that the presenting of bills to the legislature, calling for an increase in the license fees for motor-trucks and motorcoaches, has become a popular hobby for the politicians from the rural districts.

In many farming sections only a limited number of heavy-duty trucks or motorcoaches of the larger size are used, these two types of vehicle finding their place in thickly settled, industrial territories. The public in general is not interested in protecting motorcoaches and trucks from excessive taxation so long as these taxes do not affect its pocketbook directly; therefore, legislators from farming districts have realized that opposition against higher taxation on these vehicles can come only from a very small minority of operators of such vehicles, namely, public carriers, contractors and private carriers, users of the types of vehicle needed in the development of industries in their particular territory. Farmers and operators of small trucks in rural districts are not interested in protecting heavy-duty trucks or motorcoaches used in industrial territories from excessive taxation. In fact, it is frequently found that these operators of small trucks support and favor high taxation on the larger vehicles, so long as taxes are not raised on trucks of from 1 to 2-ton carrying-capacity.

In some States, license fees have not as yet been boosted to excessive limits, but it will be only a matter of time before the legislators in those States will find ways and means to raise the license fees, to what limits no one can tell. Not in the Model Act of 1926, nor in any of the publications issued by the N.A.C.C. or any other organization, has any attempt been made to set up a recommended scale of what the license tax on motor-vehicles should be. This is a matter which requires deep and extensive study and no one individual

NATIONAL AUTOMOBILE CHAMBER OF COMMERCE
366 Madison Ave. at 46th St., New York

April 24, 1929.

ATTEMPT TO DOUBLE TRUCK FEES IN NEW JERSEY ROUTED

TO MEMBERS OF THE
MOTOR TRUCK COMMITTEE

Gentlemen:

Republican leaders of the New Jersey legislature decided in the last days of the legislative session to obtain an extra million dollars of revenue by doubling the fees on motor trucks weighing with load in excess of 10 thousand pounds.

This attempt was abandoned when the Motor Truck Club of New Jersey brought to bear so much pressure on the members of the legislature that no one was willing even to introduce the proposed bill.

While the Motor Truck Club went through the motions of notifying other organizations, bringing pressure to bear on political leaders where it was possible, following the usual routine of the Truck Association work in fighting such measures I believe the overwhelming defeat of this project was due largely to the fact that five thousand leading truck owners of the state, evenly distributed in every legislative district, were promptly notified of the proposal and told they must work fast to defeat it. The result was that when leaders of the Truck Club went to the State Capitol of Trenton to lobby against the measure, they were told by every member of legislature with whom they talked to forget about it, that the legislators had been deluged while home over the week-end with personal calls, telephone messages and telegrams from twenty-five to two hundred constituents each.

Attached are copies of the circulars sent to truck owners by the Truck Club and which were tied together with the membership campaign in which the Chamber is aiding the New Jersey Club.

Apparently this is a method of resisting unfair truck tax increases which would be helpful in other states if the truck owners' organizations had sufficient initiative, intelligence and funds available.

Sincerely yours,
Edward J. Loomis
Secretary, Motor Truck Committee.

FIG. 5—ATTEMPT TO DOUBLE TRUCK FEES IN NEW JERSEY ROUTED

or organization can ever hope to set up a scale acceptable on a Nation-wide basis. Should a scale of that kind be set up, however, it is reasonable to assume that license-tax fees should be based on a per 100-lb. net or gross vehicle-weight, and the fees should be as low as possible, with a maximum fee of not more than $50 for the heaviest type of vehicle. Necessary funds for construction and maintenance of highways can be raised through a more equitable method, the gasoline tax.

Data and Suggestions on Gasoline Tax

The collecting of a tax on gasoline is in force in all of the States, this tax ranging from 2 to 6 cents per gal. During 1929, only three States did not levy this tax, but the legislators in those States during 1929 enacted laws providing for the collection of a gasoline tax during 1930. A reasonable gasoline tax is a most equitable way to collect the necessary funds needed for construction and maintenance of highways, and it has been conceded by authorities on this subject that this tax should not exceed 3 cents per gal. With a reasonable gasoline tax, every passenger-car, motor-truck or motorcoach is taxed according to its weight and the miles of highway usage. Operators pay as they go; they pay per mile of highway used and according to the weight of the vehicle, for it takes a certain amount of gasoline to produce a given horsepower to move a certain weight over a certain distance. No man-made law could devise a more equitable method of taxation than this.

Table 5 shows how this equitable distribution of taxation is automatically accomplished. As the figures indicate, a light vehicle making 25 miles per gal. of gasoline and traveling 100 miles on 4 gal. contributes 12 cents to the State highway fund under the 3-cent gasoline tax, a car making 15 miles per gal. contributes 20 cents for the same distance, while a large truck or motorcoach making only 5 miles per gal. pays 60 cents in gasoline tax for the same distance; a heavy-duty tractor-truck, with semi-trailer and four-wheel trailer, a combination commonly used in transporting heavy tonnage, may only make 2½ miles per gal. and therefore contributes $1.20 in gasoline tax to cover the same distance of 100 miles.

There are other good reasons why operators of commercial vehicles should give support to a reasonable gasoline tax and, if the entire amount of money required to construct and maintain highways could be raised through the gasoline tax only and other taxes on motor-vehicles entirely eliminated, the rate of taxation would be on a more just and equitable basis because every operator would pay in exact proportion to the mileage traveled and the weight of the vehicle.

You Will Have to Work Fast

Next week the legislature will put over a bill to increase fees on motor trucks 100 per cent—unless you get busy at once with your representatives and urge them to vote against it.

This is the last week of the session and we will not be able to get a hearing on the proposed bill.

We are doing everything we can, but nothing will be more helpful than a personal word from you to your representatives.

There are 75,000 owners of New Jersey's 125,000 trucks. For 10 years this club has had an average membership of 1000 owners who pay $10 a year to make sure that laws and taxes affecting trucks are fair.

This work can be handled more successfully if we have more members and more money.

We can do a good deal for you, as you will see for yourself if you will read the two folders enclosed.

One of our members tells us that he thinks it is cheaper to belong to the club than to stay out. Certainly if this plan for doubling truck taxes goes over because only 1000 out of 75,000 owners are willing to work together and support the club, you will lose in one year many times the price of a year's dues.

There is an initiation fee of $5 the first year. You will find an application blank on the back of one of the folders.

MOTOR TRUCK CLUB OF NEW JERSEY
343 High Street, Newark, N. J.

FIG. 6—PLACARD TO STIMULATE EFFORT

In conclusion, there are no better words suited to express properly the urgent need for action on the part of the automotive industry than those used by Alfred Reeves in his remarks at a recent Rotary Club meeting in Detroit, as follows:

> The only threat to Michigan's motor prosperity lies in these continuous attempts to pluck the motorist. We must protect the home market against the irresponsible raids on the motorist's pocketbook, which are becoming all too general. We have never protested against any reasonable taxation of the motor-vehicle for legitimate highway-purposes. Danger in the situation lies in the continuous temptation of legislators to raise the gasoline tax a cent or two for the sake of some revenue purpose other than transportation. This is class legislation defensible only if the funds are to be expended for highways, and even then any increase above 2 or 3 cents per gal. should be watched with a great deal of care.

The *Automotive Daily News*, commenting on Mr. Reeves' remarks, says:

> For our part we are not at all sure that the automotive industry has not been a little supine in its attitude toward the rising flood of legislative imposts

TABLE 5—REVENUE FROM A 3-CENT GASOLINE-TAX FOR A DISTANCE OF 100 MILES[15]

Miles per Gal.	Gal. Used	Tax
25	4	$0.12
20	5	0.15
15	7½	0.20
10	10	0.30
5	20	0.60
2½	40	1.20

[15] Concerning the gasoline tax for 1929, 3 States have none; 9 have a tax of 2 cents per gal.; 10 have 3 cents; 1 has 3½ cents; 17 have 4 cents; 8 have 5 cents; and 1 has 6 cents.

on the motor-vehicle and motoring. We believe that an organized fight against this mulcting of the motorist should have been started before this. We believe that the time has come for the automotive industry in all its branches to organize for a bitter fight against further legislative imposts on motor transportation, which is now in many States a serious obstacle to development. Motor-trucks and motor-coaches in some States are now so heavily taxed that profitable operation is almost impossible. Manufacturers of, dealers in and users of motor transportation represent a majority of the voters of this Country. Any time they desire to stop legislative aggression against their interests they can do so. The time has come to organize the automotive interests of the Country, including vehicle owners, to stop the further hampering of automotive development by State legislators.

The remarks of Mr. Reeves and the comments from the *Automotive Daily News* are very much to the point. Only through coordination of efforts can we hope to accomplish results.

Amendments to New Jersey Laws Killed

A very good example of how a well-organized State-organization succeeded during 1929 in killing a proposed amendment to the State Laws in New Jersey, and saved truck operators from an increase of 100 per cent in the license-tax fees, is given in the accompanying letter and placards. (See Figs. 5 to 7.) It should be noted how the Motor Truck Club of New Jersey met this attack and won the fight. Strength lies in organization.

APPENDIX

The National Conference on Street and Highway Safety, assembled at Washington during the week of May 25, 1930, revised the 1926 Code on Sizes and Weights for Commercial Vehicles. The Motor-Vehicle Conference Committee of the National Automobile Chamber of Commerce reviewed the Safety Conference Code on June 5, 1930, and partly endorsed the new Code, except the height and width limitations. These are given in Table 6.

Motor-Vehicle Weight-Limitations

A new weight-schedule for commercial vehicles was adopted by the National Conference on Street and Highway Safety, submitted by the United States Bureau of Public Roads, as shown in Table 7.

No motor-vehicle having a minimum axle-spacing of less than 40 in. shall be driven on any highway in any area. Subject to the maximum axle and wheel loads specified in this Section, the gross weight of any motor-vehicle or combination of vehicles on major roads in metropolitan areas shall be fixed within safe capacities of the bridges existing in the area. Subject to the maximum axle and wheel loads specified in this Section, the gross weight of any motor-vehicle or combination of vehicles driven upon major roads of industrial and agricultural areas shall not exceed that determined by the following formula:

Where bridges are designed under Class H-20 specifications, the total gross load in pounds equals 1330 ($L/40$) in which L represents the over-all distance in feet between front and rear axles of the motor-vehicle or first and last axles of the combination of motor-vehicles. Where bridges are de-

We Win This Year!

Two weeks ago it was decided to rush thru in the closing days of the 1929 session a Bill increasing truck fees 100%.

A week later, on the day the Bill was scheduled for action, no legislator could be found to lend his name to the measure, as the clipping to the right indicates.

This complete change of heart did not come by accident.

SOME ONE discovered the plan to double truck fees the day it was decided upon.

SOME ONE notified dozens of organizations of business men all over the State.

SOME ONE notified you as one of 6,000 leading truck owners of the State.

SOME ONE arranged for bus loads of truck owners to visit Trenton the night the Bill was to be acted upon.

SOME ONE provided headquarters and directed the campaign to fight an unjust tax assessment on one of the essential industries of the State.

This "SOME ONE," in each and every case, was the MOTOR TRUCK CLUB OF NEW JERSEY.

Since 1914 it has been continuously on the job as the "Watch Dog for Motor Truck Owners."

For 10 years it has had an average membership of 1,000 of the wide awake truck owners of the State.

It did not cost you a cent to stop the proposed 100% increase in truck fees, but it has been costing 1,000 truck owners $10.00 a year for 10 years. And it has been dirt cheap for them at that.

NEXT YEAR???

Altho we won this year, we are told by Legislative leaders that truck taxes are going higher next year. Truck owners are willing to pay their fair share of highway costs, but it must be a FAIR SHARE—and in proper proportion to taxes paid by other highway users.

HOW TAX INCREASE DIED

Mystery Measure Appears in House

Assemblymen Deny Parentage of Bill Raising Motor Truck Fee

Trenton Bureau, NEWARK NEWS.

TRENTON—The House found in its files today an important bill that no one would sponsor. It was a measure, supposedly introduced last night, designed to increase by 100 per cent the license fee for heavy motor-trucks.

Minority Leader Barlson discovered the bill's existence today in newspaper reports of its introduction. He had assured motor-truck interests he would not give unanimous consent for introduction of the bill.

Barlson took up the bill with Speaker Gabrielson, who also was surprised. He said the bill had gotten into the records without consent of the majority and minority leaders.

Assemblyman Siracusa of Atlantic, recorded as sponsor of the bill, was amazed when he heard of its introduction. He said he had told truck owners he would not introduce such a measure and that some one must have placed it on the clerk's desk with his name on it.

He added he had no interest in the measure, no part in its introduction, would not support it and had never seen it. He also said he could not understand how the bill got on the clerk's desk. Further he argued that if allowed to remain in the records of the house it would not be pressed for passage by him. He said he was sorry the incident had occurred, but could not explain it.

From NEWARK NEWS, April 16, 1929

The Motor Truck Club of New Jersey will fight for your interests next year as it did this year. But its chances for success depend upon the extent and character of its membership, and in having sufficient funds to do its work well.

You are the sole judge as to whether it is the part of wisdom, as well as good business, to ally yourself with 1,000 other truck owners now members of the Motor Truck Club of New Jersey.

MOTOR TRUCK CLUB OF NEW JERSEY,
343 High Street, Newark, N. J.

Gentlemen:

I want to support your efforts for a square deal for trucks. Enclosed is check for $15.00 to pay my Initiation Fee and Dues for one year.

Firm Name ..... Nature of Business .....

Representative's Name .....

Business Address: Street ..... Town .....

FIG. 7—ANOTHER EFFECTIVE PLACARD

TABLE 6—CODE REVISIONS MADE IN 1930

	National Conference on Street and Highway Safety, Washington, D. C.		Motor-Vehicle Conference Committee, National Automobile Chamber of Commerce, New York City	
	1926	Revision of May 25, 1930 (Adopted)	1923	Revision of June 5, 1930 (Recommended)
Height, ft.	14½	12	14½	14½
Width, in.	96	96	96	108
Length for a Single Vehicle, ft.	33	33	33	40
Length for a Combination of Vehicles, ft.	85	85	85	85
Gross Weight for a Four-Wheel Vehicle, lb.	32,000[a]	None	28,000	None
Gross Weight for a Six-Wheel Vehicle, lb.	38,000[a]	None	None	None
Maximum Four-Wheel-Truck Axle Weight, lb.	25,600[a]	See Table 7, New Weight Schedule	22,400	See Table 7, New Weight Schedule
Maximum Six-Wheel-Truck Axle Weight, lb.	16,000[a]	See Table 7, New Weight Schedule	None	See Table 7, New Weight Schedule

[a] These weights in the 1926 Code apply to Class-*A* highways only.

signed under Class H-15 specifications, the total gross load in pounds equals 1000 ($L/40$). Where bridges are designed under Class H-10 specifications, the total gross load in pounds equals 670 ($L/40$).

THE DISCUSSION

J. F. WINCHESTER[16]:—Mr. Schon has set forth certain matters that are very interesting. He analyzes certain work that has been done in New Jersey. Having been one of the original organizers of the Motor-Truck Club of New Jersey and having had a great deal of contact with that organization, serving as its secretary for about eight years and its president for a year, I have had the opportunity to study some of the various parts of the problems that enter into successful work along such lines.

This Club was organized at a time when operators had but little education, as compared with present-day knowledge, in matters relating to automotive transportation, and therefore a large group of men from all parts of the State who took great interest in such affairs banded together. The result has been that, over a period of 10 years, well-directed cooperative efforts have been made with legislative bodies. This certainly has had a good effect in the formulation of liberal laws. I am inclined to believe that New Jersey has a more liberal set of laws than that of any other State in the Union, and that it will continue to maintain this reputation.

[16] M.S.A.E.—Superintendent of motor-vehicles, Standard Oil Co. of New Jersey, Newark.

[17] See S.A.E. JOURNAL, August, 1930, p. 187.

[18] See S.A.E. JOURNAL, February, 1930, p. 235.

TABLE 7—NEW WEIGHT-SCHEDULE

Kind of Highways	Maximum Weight for Pneumatic Tires, Lb.		Maximum Weight for Solid Tires, Lb.	
	Wheel	Axle	Wheel	Axle
Major Highways in Metropolitan Area	11,200	22,400	11,200	22,400
Major Highways in Industrial Area	9,000	18,000	7,200	14,400
Major Highways in Agricultural Area	8,000	16,000	6,400	12,800
Secondary Highways; Subject to Seasonal Restrictions	8,000	16,000	4,000	8,000

On the other hand, manufacturers' representatives should keep clearly in mind the fact that a great amount of restrictive legislation which has entered into present laws has been brought about through shortsightedness, or perhaps greediness, on the part of their own organizations. If it were only possible to get a controlling interest of these large manufacturing organizations together, so that they could agree upon a number of fundamentals regarding both engineering and sales, it certainly would be much easier for the organized operator than is the case at present. Jockeying for sales position by manufacturers has caused more restrictive legislation than any other thing of which I know. A frank paper of this kind establishes a common basis upon which they can discuss the various problems. To my mind, they constantly should devote very careful thought and make very capable analyses of the various factors that cause adverse legislation.

Under "engine changes," in his paper on Weight and Size Trends in Motor-Truck Development[17], Mr. Schon mentions six-wheel vehicles to carry heavier tonnage-loads on balloon tires at passenger-car speeds. I believe that there is apt to be a very serious reaction toward passenger-car speeds or those of motor-trucks themselves if the manufacturers persist in advocating higher and higher road-speeds for these heavy-duty units. Reference should be made to my comments on this in my discussion of A. A. Bull's paper on Governors[18].

Under the heading Laws Handicap Motor-Truck Design, Mr. Schon points out that certain statistics have been compiled by the State of Massachusetts. I think it would be to the engineering fraternity's advantage and to that of the industry as a whole, if these statistics were printed and circulated.

It is rather surprising to me to find in Mr. Schon's paper reference made to the work done by the Bureau of Public Roads and then to find that, in another section of the paper, he advocates an arbitrary basis of reducing the axle weight of equipment running on solid tires. The Bureau of Public Roads has done very good work along these lines, and I think we should be guided closely by the data therein, after careful analysis has been made. I have but little confidence in that part of the table submitted which shows that there should be 20 per cent less weight when equipped with solid tires. Why should there be less weight for solid tires when, in the paragraph on Pneumatic versus Solid Tires it is stated that "the percentage of increase in static load to the capacity is less as the load was increased," because of the "closer adherence of the truck wheel to the road."

T. H. MacDonald, of the Bureau of Public Roads,

has clearly set forth that a vehicle with solid tires of proper carrying-capacity up to a gross weight of 28,000 lb. does no material damage to a properly constructed highway if operated at proper speeds and, with this as a basis, the Uniform Motor-Vehicle Act was formulated which advocates the foregoing gross weight. If the tests conducted by the Bureau show that a weight of 28,000 lb. on solid tires at a given speed does no damage to the highway, then it is logical to assume that, in view of the tables which have been presented by Mr. Schon, when equipped with pneumatic tires a vehicle actually should be permitted to have its gross weight considerably increased provided pneumatic tires of sufficient capacity can be provided for such a load.

In view of the foregoing statement, I can see no logical reason why the gross weights on pneumatic tires should not be extended considerably beyond the range indicated by Mr. Schon. Statistics actually will show that the number of heavy-duty trucks which get out of city limits is very small as compared with those operating within cities. As highways within these districts are usually constructed to carry gross weights of such character, I can see no good reason for the universal application of such a rule as Mr. Schon advocates.

Under the heading Taxation of Motor-Vehicles, it is set forth that the tax on gasoline is the best method of taxation that can be devised and the fairest one that can be adopted. This may be true, but there is one feature which is unfair that affects the industry with which I am associated. In the majority of cases no provision is made to compensate petroleum companies for the work they do in its collection, and in some States an impost is placed against them because they must pay the tax on all gasoline sold, even though they may not actually have collected from the customer. This type of business actually falls under the classification of "bad debts" and, where this occurs, legal provisions should be made to collect direct from the party at fault rather than from the vendor. I hope that, within the next year or more, a careful study will be made by manufacturers and transportation men of the points raised by Mr. Schon, which surely will lead to constructive results.

Proper Spacing of Axles

DONALD BLANCHARD[19]:—In the table of practicable weights for commercial vehicles, presented by Mr. Schon, mention is made of 8-ft. spacing of axles, and the classification is made to cover both greater and lesser spacing. Why is that done? The Bureau of Public Roads conducted an investigation in Illinois, and found that there was no concentration of stress in the pavement over that obtained with one axle, if the axle spacing was more than 36 in.

PIERRE SCHON:—That is to include protection of bridges. Highway engineers are opposed to concentrated weight on bridges. The 8-ft. spacing or even a 10-ft. spacing would be practicable and still more acceptable to the highway engineer. Tests made in Illinois proved out the same results as obtained by the Bureau in Virginia. Six-wheel trucks with pneumatic tires are allowed a 40,000-lb. gross-weight in Illinois, and these tests proved that 40,000 lb. was not excessive on pneumatic tires for any good concrete pavement of Class-*A* type.

Standardization of Loading Space

R. E. PLIMPTON[20]:—Mr. Schon has brought out one very definite suggestion. It is that the Society ought to standardize on loading-space dimensions, and he has implied that somebody should organize to fight this harmful legislature. He says that 41 legislatures had 2500 amendments affecting design, manufacture and operation of motor-vehicles during 1929. I am surprised that the number was so low. From my experience, with 41 legislatures in session, the number of amendments easily might have been 5000. But 1930 is an off-year, fortunately, in that only about 10 legislatures will be in session and we can have some relief from such a flood of proposed restrictive legislation. However, if we are to fight detrimental legislation in the way it should be fought, we must cooperate with organizations such as the Motor-Vehicle Conference Committee, which has a definite plan, and the National (Hoover) Conference on Street and Highway Safety.

Mr. Schon's paper must be considered if the recommendations are to be used in some way to determine the Society's policy, but I cannot conceive it as being desirable that the Society should actively favor or oppose legislation. That is a specific job. There are people who are competent to do it, and I think it is a very proper function of the State Truck Associations to go into such work. The Society is organized for the purpose of determining principles that should be followed by these Associations. If we simply select certain principles in connection with the method of determining weight allowance or gross weight, and go on record in favor of them and publish them, any such Associations, which are directly on the firing line, can put them forward at the proper time as constituting the recommendation of the Society. That is as far as the Society should go.

Proposed Laws and Amendments

Mr. Schon is enthusiastic in condemning some of the actual or proposed laws and amendments. I have had occasion during the last few years to visit nearly all of the State regulatory commissions, which are concerned mostly with motorcoach and motor-truck operation, and the public carriers that the paper mentions. In general, they are fair and willing to do all they can. The great danger is, and it applies particularly in the West, that detailed requirements are enacted into statute law and then it is very difficult or almost impossible to change them. I think it is better not to bind the commissions too closely. In case they are unreasonable, there is a remedy through an appeal to the courts. Therefore the conditions are better than if details were enacted into laws which cannot be changed or which, if not enforced, are likely to cause trouble.

F. C. HORNER[21]:—My understanding is that Mr. Schon is addressing the automotive industry in general in his very comprehensive paper covering a subject that has not as yet been dealt with in an intelligent manner. Secondly, he is addressing a transportation session of the Society of Automotive Engineers, and he has paraded before us the problems that face us as manufacturers and operators of commercial motor-vehicles. Regarding just what action we should take in the light of what

[19] M.S.A.E.—Editor, *Automobile Trade Journal*, Chilton Class Journal Co., Philadelphia.

[20] M.S.A.E.—Associate editor, *Bus Transportation*, Chicago; now transportation engineer, The White Co., Cleveland.

[21] M.S.A.E.—Assistant to vice-president, General Motors Corp., New York City.

he has presented is a question, I think, which should be presented to the Transportation and Maintenance Activity Committee of the Society and, in turn, to the S.A.E. Council, with reference to recommendations that possibly might be made in connection with legislative matters. I agree with Mr. Plimpton that fighting legislation is not our job. However, we could make recommendations to the Motor-Vehicle Conference Committee or to the National Automobile Chamber of Commerce. No matter what we might do, we can at least try to do our part to correct the situation which, as Mr. Schon has very ably shown, is a very serious one from very many standpoints.

We are facing a serious situation for the next few years unless we can put our house in order, not only from the standpoint of legislation but from the standpoint of a multiplicity of body dimensions and all the other duplications of construction we have allowed to creep in. The various motor-truck clubs and motor-truck associations throughout the various States, wherever they are functioning to advantage, are real live organizations. They can be brought into this campaign through the proper channels and in a way that will not involve the Society in any entangling alliances or result in adverse criticism.

Perhaps it was not the job of the members of the Society to deal with the legislative side, but unless somebody does deal with it, where would the industry be headed for in a year or so? Only a few State legistures meet in 1930; but, in 1931, the legislatures of about 42 States will meet and numerous bills will be presented which will affect the automotive industry adversely—and the operators of motor transport in particular—if the bills pass; so I think it is very timely that we should deal with these very important subjects that Mr. Schon has presented.

Trailer Transport Affected

W. G. RETZLAFF[22]:—In figuring on trailer installations, we find that about 50 per cent of the operators travel through more than one State. In about 50 per cent of such installations, it is necessary for us to advise the operator to curtail his load or else to pull only one trailer, so as to comply with the various State laws. New York City receives a large amount of its freight shipments by truck through Connecticut, and yet the truck industry has been handicapped greatly because of the stringent legislation in that State. New York State permits the use of two trailers, as does Pennsylvania, yet practically all the truck shipments between Philadelphia and New York City must pass through New Jersey, which permits the use of only one trailer, thereby forcing the operator to reduce his payload to almost one-half capacity. We in the trailer industry would much prefer a standard axle-rating as suggested in Mr. Schon's paper.

Tire Equipment Discussed

J. E. HALE[23]:—Two different aspects of Mr. Schon's paper appeal to me especially. The first is that it is gratifying to me to have tire equipment recognized so prominently and on such a common sense basis as Mr. Schon has done. It is about the first time that tires have been given such prominence as a fundamental in transport work. I can see that Mr. Schon is fully familiar with the latest development in tires, and I emphasize that we are on the verge of applying balloon tires to motor-trucks. Solid tires are being discontinued so fast that they will be forgotten in a short time, and any future considerations regarding tire equipment for heavy-duty units should be based on a discussion of balloon tires and nothing else.

Concerning legislation and all the complications of the laws, the tire companies are implicated because those who enforce the laws find it easy to find fault with some aspects of tire equipment; hence, the truck operators are beset and do not know what to do. Then they come to the tire companies for advice.

I would like to have some definite proposal made. What are we going to do about it? There is certainly any amount of evidence that we are faced with a difficult situation. Many truck operators probably know this, but many other people should know about it and I would like to see some action taken. It seems to me that the first thing to do is to get the Hoover Code and the N.A.C.C. Conference Committee's code brought up-to-date. Manifestly, they contain some out-of-date features, and I propose that we devise some rule that we could recommend that would get revision started. If we can get those two codes brought up-to-date, the next step would be to give publicity to the ridiculous phases of the laws, as Mr. Schon has brought them out; business men and other people will respond to it if they can be reached.

As to the means of reaching the public, that is at hand. The distribution organizations of all the truck companies and all the automobile clubs can be used to handle that phase. I am most familiar with the tire end of the business. We have thousands of dealers, our dealers have salesmen, and we have our own salesmen. I see no reason why our company and all other tire and truck companies could not act on a proposal to them that they distribute instructions down the line to their employes so that these men would try to educate the public and create sentiment in favor of logical and reasonable attention to the legal aspects of the subject and to the construction of laws.

A. J. SCAIFE[24]:—I am vitally interested in the proposal outlined by Mr. Hale and I think the Transportation and Maintenance Activity for 1930 could care for that kind of work. It was not a very difficult job to change from solid to high-pressure pneumatic tires; but when changing from high-pressure pneumatic and from solid tires to balloon tires, a distinct designing problem is presented with reference to frame widths; to wheels, as to tire spacings; and to over-all width of the rear axle to carry the load. If we use the balloon tire on heavy-duty trucks, providing proper clearance between the inside of the tire and the frame and between the tires themselves—including six-wheel trucks, four-wheel-drive and six-wheel utility trucks—the vehicles will be wider than 96 in., which is the maximum width that most of the laws permit.

For example, if we consider the standard 400 series Timken axle that uses 40 x 8-in. high-pressure tires, balloon tires would make it more than 96 in. wide. Therefore, from a design standpoint, the Motorcoach and Motor-Truck Divisions of the Standards Committee and the Activity Committee should give consideration to

[22] M.S.A.E.—Transportation engineer, Fruehauf Trailer Co., Detroit; now engineer, General Motors Truck Co., Pontiac, Mich.

[23] M.S.A.E.—Development department manager, Firestone Tire & Rubber Co., Akron, Ohio.

[24] M.S.A.E.—Consulting field engineer, White Motor Co., Cleveland.

this and determine whether it is possible to work out, with the tire companies, a plan relating to the proper widths and spacing and clearance for tires, and then to compare that layout with that of present chassis and see what obstacles must be surmounted. It is a bigger job than the motor-truck manufacturers can handle alone. Instead of going at it individually, we ought to undertake it as a Society, to see first what can be done about it as a whole. Then we should have a concrete basic plan to present, possibly to these other bodies, through our Transportation and Maintenance Activity Committee which, I believe, is a logical agent which can present worthwhile S.A.E. data to the proper association.

MR. PLIMPTON:—The Transportation and Maintenance Activity Committee already has given a great amount of consideration to this subject. Under Mr. Horner's competent leadership, I am sure that the Committee will make further progress in this matter very soon.

MR. HORNER:—In that connection, the Committee proposes to have a subcommittee of the Transportation and Maintenance Activity Committee, acting with the Motor-Truck and Motorcoach Committee jointly, to investigate the matter of standardization of dimensions and to determine what can be done to improve the situation.

Proper Procedure Considered

I am rather concerned as to just what the proper procedure should be regarding the points brought up by Mr. Hale. I agree with Mr. Plimpton that it is not wise for the Society to show direct interest in legislative matters. Whether the problem has been neglected by those who are in a position to handle it, and have handled it in the past, I do not know, nor whether it is practicable for us now to attempt to pass some message on to some of the bodies that are logically constituted to deal with this problem of adverse legislation. But I think we ought to give very serious consideration to the suggestion brought up by Mr. Hale.

MR. HALE:—Considering that most of the States do not convene their legislatures until 1931, now is the time to get this matter into shape, because it is not an easy thing to accomplish and will take time. We can only make a start now, and work toward creating public sentiment during the interim. Then, when the legislators convene, they will be faced with public sentiment.

A matter such as this is likely to drag along because nobody does anything until they are right in the midst of trouble. Then there is no time to organize and combat it. That is why I urge that we do something now. If the Society could cooperate with the National Automobile Chamber of Commerce, the Rubber Manufacturers' Association and similar bodies, in bringing the substance of Mr. Schon's paper before some of the leaders of the automotive industry, impressing upon them just how much the transportation industry of this Country has been handicapped by foolish legislation, they will cooperate in fighting against it. If the leaders of the motor-truck industry have the necessity for preventing legal limitations on motor-trucks impressed upon them, I believe that they will respond and find a way to do it.

License Fees Commented Upon

F. K. GLYNN[25]:—It may be of interest, in line with this subject, to outline the various ways in which license fees are calculated in these "United" States. In order, fees are based on the N.A.C.C. horsepower-rating, flat or nominal rate, total load-capacity, net weight of the complete vehicle, net weight of the chassis, gross weight of the complete vehicle, percentage of the value, displacement in cubic inches and total tire-width. In addition, one which only a lawyer could figure out, is called "multiple or percentage of pneumatic-tire width."

For example, considering a car of say 2500-lb. gross weight, the license fee in one State is $3; in another, $6; in a third, $35; and in a fourth, the District of Columbia, $1. The fees for a ½-ton truck in three different States are $5, $15 and $25. For a 2½-ton truck with pneumatic tires, the fees run from $30 to $300, with the District of Columbia at the $1 nominal fee. For a two-wheel trailer the fee in one State is $116, in another State no fee whatsoever, in a third $19 and in a fourth $50. There is no uniformity.

As one of the fraternity which must analyze, study, and comment upon proposed motor-vehicle legislation for every State in the Union, I favored the Hoover Code when it first came into prominence because I figured that uniformity, even with the faults this Code has, would be preferable to the present situation. But the first legislator, believing he must be original, changed it in certain parts; the next proponent in the same legislature changed it again, so that it soon became anything but a Hoover Code.

CHAIRMAN B. B. BACHMAN[26]:—Mr. Hale and several others have asked what we are going to do about fighting adverse legislation. I may be wrong in interpreting the general sentiment of this meeting, but I shall not ask that any "resolution" be passed by this assemblage. It seems to me that the general sense of this meeting imposes an obligation on Mr. Horner, who is Vice-President of the Transportation and Maintenance Activity Division, and on Mr. Scaife, who is Vice-President of the Motor-Truck and Motorcoach Activity Division. It seems to me that the Divisions which the Society created in its constitutional amendments, and the representation that is given to the various Divisions of the Council, have afforded direct means for carrying out the ideas which have been proposed here. Therefore, with your permission, I shall ask Mr. Horner and Mr. Scaife to be active in this work throughout the year 1930.

[25] M.S.A.E.—Engineer, operation and maintenance of automotive equipment, American Telephone & Telegraph Co., New York City.
[26] M.S.A.E.—Vice-president of engineering, The Autocar Co., Ardmore, Pa.

Two Maintenance Plans Compared

Oral Discussion of H. V. Middleworth's Semi-Annual Meeting Paper[1] on Self-Maintenance versus Service-Station Maintenance

IN THE ORAL discussion it is stated that the Public Service Coordinated Transport of New Jersey has a bonus system for freedom from accidents. Drivers receive a bonus every month during which they do not have an accident, a conditional bonus every three months, and a yearly bonus; that is, if they drive for a year without an accident, they receive an additional bonus. A driver's record is kept very carefully. If a driver has a number of accidents he is reprimanded; if he has several accidents, he is laid off for a period; and after having had a certain number of accidents he is discharged.

The Bell telephone system is one of the foremost exponents of accident prevention and safety, according to F. K. Glynn. Its officials believe that there is only one way to do any single operation and that is the safe way; therefore, safety and accident prevention are a part of every employe's regular job.

A. F. Coleman says that, while operating the Pierce petroleum fleet in the West, a strike occurred. During the strike this company closed its shops through a certain section of the West and operated on the basis of using manufacturers' repair-shops as a means of taking care of the equipment.

Leo Huff remarks that he has operated under the various systems and has found that a man taking over the duties of operating a fleet, regardless of how small or large it may be, must study the individual fleet. Ralph Baggaley, Jr., states that, in considering whether or not a fleet operator will have self-service or service-station maintenance by the manufacturer, we must consider more than the cost per mile for the vehicles operated, because we also should take account of the number of days out of service that either of these services will give.

Temple C. Smith states that there is a very definite relation between the maintenance and the depreciation of motor-vehicles. O. M. Brede says that the discussion in general seems to lead toward an agreement that a combination of the systems is still the right answer at this time. H. C. Marble agrees with Mr. Brede's statements and believes the whole question, especially with reference to the concentrated fleet, is open for individual study. This led M. C. Horine to say that in one case, service-station maintenance may be more expensive and, in another case, cheaper. He believes that no adequate general answer can be made to a general allegation.

Other subjects touched upon include the running repairs and maintenance of a fleet handled in the owner's garage, major repairs in the manufacturer's service-station, repairs which can be made overnight, and similar topics.

In conclusion, Mr. Middleworth sums up the voluminous discussion and says that each individual fleet-owner should make a very careful survey of the conditions under which he operates and then decide whether self-maintenance or service-station maintenance is the better method to pursue. He believes that it is not possible to make any hard and fast rule as to how and when vehicles should be reconditioned, or to specify in detail what methods should be adopted.

THE ORAL DISCUSSION

CHAIRMAN F. C. HORNER[2]:—There are two things in Mr. Middleworth's paper that impressed me as being very important. In one paragraph he makes two statements; first, "Before any definite conclusion is reached regarding the advisability of service-station maintenance, a careful study should be made of the conditions under which the fleet operates." The second one is, "If after careful study it is decided that service-station maintenance is desirable, a thorough survey should be made of the service-station facilities available in the districts from which the vehicles operate."

The point to which I call attention is that one must know what the problem is before one can find the proper solution of it. Very frequently, operators of what might be said to be medium-sized operation, say 15 to 20 trucks, are apt to go wrong because they do not make a careful study of their problems. Unless one knows the facts, he cannot deal with them intelligently.

In the prepared discussions, it should be noticed that three men report from the operating field, three from the manufacturing field, and one from the U. S. Army. That is a fair set-up. What Mr. Schreiber said about the London General Omnibus Co. is interesting. When I looked over its operations in 1922, I discovered that it is the only operating company which repairs and maintains on a production basis, one might say; that is, the company schedules a certain number of vehicles daily to go through the large repair-shops at Chiswick. That is because the police department at Scotland Yard requires that every vehicle must be relicensed annually and, when it is relicensed, that it must be in tip-top shape or the Department will not pass it. It must practically be overhauled before the operator dare try to get a new license for it. Many advantages are to be gained by this practice. The vehicles are seldom refused a relicense because they are completely overhauled and repainted before being sent for relicensing.

H. W. ALDEN[3]:—What efforts are made by Mr. Ly-

[1] Published in the S.A.E. JOURNAL for August, 1930, p. 197, together with the prepared discussion. Mr. Middleworth is a member of the Society, and superintendent of operations in the transportation department for the Consolidated Gas Co., New York City. A statement of the major points in the oral discussion is printed herein.

[2] M.S.A.E.—Assistant to vice-president, General Motors Corp., New York City.

[3] M.S.A.E.—Chairman of the board, Timken-Detroit Axle Co., Detroit.

man's company as to penalties against drivers for accidents, or to apply the bonus and the honor-systems for freedom from accidents and excessive maintenance cost of the vehicles it operates?

A. A. LYMAN[4]:—We have a bonus system for freedom from accidents. Every four months each driver who has not had more than three accidents in that period receives a bonus, the amount of which varies according to the number of accidents. Drivers having a clear record for a year receive an additional bonus.

Records are kept very carefully; they cover the complete history of each operator. The penalty for an accident, in addition to loss of bonus, is either a reprimand, transfer to the extra-operators' list for a period, lay-off, or discharge, as the particular circumstances may warrant.

DAVID BEECROFT[5]:—What percentage of the motor-trucks operating in this Country in fleets of all sizes is represented by the large-fleet group that has for consideration self-maintenance?

In the publishing field we had many arguments some years ago regarding the costs of certain practices. It was rather difficult to get the different publishers to agree on a standard for estimating. One of the national accounting firms was engaged, and it made a very broad study over many groups. I wonder if the cost figures as used by these different groups of fleet owners are understood in their real fullness, or if some standard accounting system or analysis is not needed?

Western Petroleum-Fleet Practice

A. F. COLEMAN[6]:—While operating the Pierce petroleum fleet in the West we had a strike. Rather than combat it we merely closed our shops through a certain section of the West and operated on the basis of using manufacturers' repair-shops to maintain our equipment during the strike. Perhaps the argument which will be used against what I am going to say is that the time during which this was necessary was too short to get ourselves properly organized to take advantage of all of the economies which the system may offer. But our experience during that period was that our operating expenses on these particular units which were worked on by manufacturers doubled the cost of the actual repairs, although this must be modified to a certain extent by overhead in our own shop. However, after allowing reasonable overhead, based on our previous years of experience, our repairs cost us fully 25 per cent more when using manufacturers' shops than they did when using our own.

In our present operation I cannot see where it would be possible for a manufacturer to give us the service which we render ourselves, and give it to us at anything like the figure that our operations are now costing us. We of course take advantage of the facilities offered by manufacturers. Our men in many cases go to the factories and learn new methods of repairing. When a machine comes out that is specially designed to speed up work and attain greater accuracy in our shops, we take advantage of it where we can, in case we have sufficient vehicles of the type going through to justify the investment. I believe that one of the compromise systems that has been suggested, if I may call it such, is probably the best answer to most of our problems.

I have seen J. F. Winchester's fleet, right across the Hudson River from us, operating for the Standard Oil Co. of New Jersey. One might think that his company's and our company's—the Standard Oil Co. of New York—positions and the two conditions which we have to meet would be identical; yet Mr. Winchester's problems are in many cases entirely different from ours. He is delivering the same product and uses the same kinds of vehicles, but in different territory. Therefore, I do not know that there is any answer other than the careful analysis of the individual's problem, and trying then to choose the system that produces the best results.

LEO HUFF[7]:—I agree with Mr. Coleman. In the last 20 years of experience that I have had in operating fleet-equipment, I have operated the numerous systems and have found that a man who takes over the duties of operating a fleet of motor-vehicles, regardless of how small or large it may be, must study the individual fleet. He may have operated a fleet for another company, possibly of the same nature and being in identically the same business, but he cannot carry on his operations in his newly acquired fleet as he did in the fleet he operated in the past.

As an example, a few years ago at one of our American Petroleum Institute meetings, a rather lengthy discussion occurred with reference to operating fleets of vehicles. Considerable criticism was directed against one operator. I said at the time: "I feel we should not criticize that man until we know." I made a special effort to investigate his situation and found he was justified in handling his maintenance as he did. I operate in about 35 States in the Union. Our fleet represents about 2000 vehicles, widely scattered, with a small number in any one locality. I find that is it necessary for me to operate with both the self-service and the service from the manufacturer. This is brought about largely because of the location; for example, in certain parts of Texas, during certain periods in the production fields, it is necessary for me to have a large fleet of trucks and passenger-cars. As no service station is available within hundreds of miles, I must have men available who can handle repairs on those vehicles. In the marketing divisions where we market our products in some of the larger cities, we find that the service from the manufacturer is the best. We then use that service.

We in the petroleum industry find that, especially in marketing, it works out better in our company to use self-service. It is very easy, in ordinary transportation, to hire a truck by the hour, day or month, for hauling products that can be placed on a stake-body truck. Where one is handling a liquid in tanks, it is a problem. I should say it is impossible to hire a tank truck to deliver oil products, and out-of-service time is a great problem with us.

I estimate that 90 per cent of our equipment in the marketing division is maintained by self-service. Should we change to manufacturers' service, we have found after careful study that we would have to increase our number of tank trucks 25 per cent. We operate with a corps of traveling camps, each one hav-

[4] M.S.A.E.—Automotive engineer, Public Service Coordinated Transport, Newark, N. J.

[5] M.S.A.E.—Manager of New York office, Bendix Aviation Corp., New York City.

[6] M.S.A.E.—Manager of motor-vehicle department, Standard Oil Co. of New York, New York City.

[7] M.S.A.E.—General manager, motor-transport department, Pure Oil Co., Chicago.

ing assigned to it a certain number of vehicles. I repeat that it is an individual job for each of us to study our own individual case. I do not believe that any of us should criticize or attempt to set up a standard as to how to maintain vehicles.

Other Factors to Consider

RALPH BAGGALEY, JR.[8]:—In determining whether or not we shall have self-service or service-station service by the manufacturer, we must consider more than the cost per mile for the vehicles in question since any difference in the length of time during which the vehicles will be kept out of service by either of these service policies is an important factor.

F. C. HORNER

While considering the benefits of the parts stock at the manufacturer's branch and the value of his trained men and his specialized tools, we also must consider that, once we start using that manufacturer's service and do not have our own service-station, we are giving the manufacturer's branch a monopoly on our service work on that make of vehicle. As any purchasing agent knows, where any one company has a monopoly on any commodity the operator will not get the best prices; in other words, the branch will have the power to fix the prices at which that service will be sold to the operator. Further, in overhauling vehicles, we find that the cost of new parts put into an overhaul amounts to more than 50 per cent of the cost of overhaul. A substantial number of these parts can be bought at a very material saving by purchasing through parts agencies; for example, bushings, pistons, drive chains and timing chains.

With regard to factory branches having complete stocks, in the city of 100,000 population in which I am located, we find that for practically every part we need we must either stock it or else get the branch manager to send for it. A complete stock of parts in a town of average size is something we do not find for any make of vehicle, no matter how many of that make of vehicle we have. The factory branch keeps its parts inventory down just the same as any dealer or operator and, to have available such parts as are needed, we find it necessary to carry our own stock.

TEMPLE C. SMITH[9]:—There is a very definite relation between the maintenance and the depreciation of motor-vehicles. It has been mentioned that it might be a good incentive to set up competition among three or four different garages operating under the same general management as to the maintenance cost on the vehicles. That really does not mean very much because the man who is sharp will trade in his cars earlier and keep down his maintenance, which, from an over-all viewpoint, may very possibly be the wrong thing to do from an economic basis. If one wants low maintenance, he should trade in his vehicles early and not run them through their probable economic life.

On one of Mr. Glynn's charts illustrating the organization for different garages, that is, Plan 1 and Plan 2, he showed in each instance an engineer on the staff of each garage superintendent. I presume that this is a set-up for a complete organization and not for a group of organizations. In instances like those of the oil companies or utility companies which maintain a large number of garages, it would be much better to have the related engineering problems handled by a general engineering staff than to have each superintendent work out his own engineering problems, duplicating many times the things which are done in other garages.

Combination of the Two Systems?

O. M. BREDE[10]:—I do not care to comment directly on any of the subjects that have been discussed except to say that it strikes me that the general discussion seems to lead toward an agreement that a combination of the systems is still the right answer at this time. It is difficult to say now just where this problem will lead to in the future. Manufacturers are doing everything possible to improve their general service situation nationally. Many hundreds of thousands of dollars are being spent not only in service stations and equipment, but in education of personnel. In our organization we operate two types of educational facilities, a continuous school in Pontiac, and traveling service-representatives for field education. I believe that, with the work the manufacturers are doing to improve service nationally, there will be more places in the future where fleet operators can economically take advantage of service-station maintenance, at least partially, if not 100 per cent.

T. C. SMITH

H. C. MARBLE[11]: I agree with Mr. Brede's statements in that I think the whole question, especially with reference to the concentrated fleet, is open for individual study. I think there is not much question as regards the scattered fleet where service stations are available and, as regards the small fleet, the service station can handle that type of work.

Regarding a statement made by Mr. Baggaley, while it is quite true that, under ordinary business conditions, placing all of the work in the hands of one individual leads to a monopoly over that situation, I think it must be taken into consideration, as I mentioned in my prepared discussion, that the problem is a mutual problem of low maintenance-cost. One does not ordinarily find that condition when the purchasing agent goes out on the market. Naturally, the automobile manufacturer has a profit in mind, but the main thing is the sale of his product. We have, in that one question, a somewhat different consideration.

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[8] M.S.A.E.—Assistant equipment engineer, Pennsylvania Department of Highways, Harrisburg, Pa.

[9] M.S.A.E.—Engineer, automotive equipment and labor-saving machinery, American Telephone & Telegraph Co., New York City.

[10] M.S.A.E.—Director of service, General Motors Truck Co., Pontiac, Mich.

[11] A.S.A.E.—General service manager, The White Motor Co., Cleveland.

Mr. C. HORINE[12]: It is very difficult to answer general allegations, particularly where the witnesses' testimony is at variance. I think it brings out the point which has been reiterated here, that it all depends on the case. In one case, service-station maintenance may be more expensive; in another case, cheaper. I believe no adequate general answer can be made to a general allegation in this case.

Regarding the statement by Mr. Coleman, I think the experience he has had is logical in that a sudden influx of service work on a large fleet into a service station which is not organized and equipped for such service would very largely be expensive. It has been stated by all the manufacturers that we believe 100-per cent service in service stations, except in the case of small fleets, is not economical; that the more complicated and more involved types of major repairs can be handled more economically in service stations, provided the volume is not too large and provided also that the work does not suddenly descend upon the service station which has not been forewarned and given a chance to equip and man itself for the service.

Night Servicing of Vehicles Discussed

MR. SMITH:—I ask Mr. Horine—who read in Mr. Whittemore's prepared discussion of running repairs and fleet maintenance being handled in the owner's garage, and major repairs in the manufacturer's service station—what he considers the proper field of maintenance in those garages?

MR. HORINE:—I believe that is somewhat covered in general in Mr. Whittemore's prepared discussion. It is a very complicated subject; but, as a rule, the repair which can be made overnight is more economical in the owner's garage than it is in the service station. The repair which requires more than a day is a major repair and can be more economically handled, except in cases of the best-equipped fleets, in manufacturers' service-stations, provided that the manufacturer's service-station in that particular locality is prepared and equipped for such service.

PAUL P. PIERCE[13]: Mr. Horine raised the question of night service. I do not believe in night service under any condition whatsoever. From the psychological standpoint it is unsound, because I believe it is impossible to get the type of men who can do the work who will work at night. One does not get the desired high-class mechanics. I do not think the man who works nights compares well with the day man. I do not see how the service station can compare basically with the company-owned station. For one reason, it has to be maintained at an expensive overhead and it naturally charges more per hour than does the company-owned station, while the company-owned station can operate at a small loss.

Mr. Marble cited an example in which a dairyman said he could save $10,000 on his investment of $100,000. The answer to that man was that perhaps he could make $20,000 on his investment. I believe if the man had decided that, on an investment of $100,000, he could save $10,000, he must have known he could not make $20,000 in the dairy business; otherwise, he would not have been operating his own company on that plan.

MR. BAGGALEY, JR.:—In regard to that proposition, the dairy owner, if he had had sufficient financial backing, could have borrowed both of those $100,000 sums and thus have had both profits. Also, a truck-manufacturer's service-station is equipped to service just the mechanical parts of that truck and not the special equipment which is put on the truck by the operator. No service station of which I know, in any part of our locality, is equipped to put new bottoms in dump trucks or straighten dump bodies, or do such upholstery or top work as is needed. Radiator, magneto, and carbureter repairing, and painting, fall in the same category. To handle the special operations handled in the large-scale fleet-operator's own shop, the truck manufacturer's service-station would either have to put in a number of special departments or else send a considerable part of the work to other shops, with consequent inevitable delays and additional transportation charges.

Continuation of the Study Advocated

ACTING CHAIRMAN BEECROFT:—I wonder whether a continuation of this subject is desired at some future time? Should any message be sent to the nominal head of this group?

MR. PIERCE:—I would like to have the study continued, but I think our discussion would be of greater advantage if we could know in actual figures from each company what the cost is per vehicle or per ton-mile over a given period under the two systems. But each case has its own grounds upon which it must operate, and all those factors must be taken into consideration. In the past we have been too prone to guard too jealously and confidentially the cost of vehicles, both in service and in operation. In the future we shall get farther along if we begin to disseminate that knowledge and reduce it to a standardization basis the same as we do in the manufacture of a part.

The time will come, after we have that information, when it will reflect in the make of the truck that is to be sold. We will find out each particular make, what it costs to operate per mile, and the consumption of gas and oil. It will be reflected in either a stepping-up or a stepping-down of the production of some one or more makes of vehicle; that, in turn, will put the manufacturer who lags behind on his toes, and he in turn will begin either to step up the quality of his product or go out of his way to increase his sales and give better service.

I know that the large-scale operators today zealously guard their cost figures, and I doubt if at this time or within the near future we are going to be able to get them to relent. But I would like to see the general discussion carried further and have a comparison of costs made between the two different systems, compiled so that we may know what the factors are that govern their choice.

MR. MARBLE:—It occurs to me that the operators and their interests are discussing this subject pro and con, and that perhaps there may be some feeling that the manufacturer is more or less on the service-station side, trying to defend service-stations. I think I am voicing the opinion of Mr. Horine's company and Mr. Brede's company that it is not so much a question of building a good-sized service-station as it is the primary fact that the manufacturer is mutually interested in low maintenance-cost. I think every one of the manufacturers welcomes any information he can get from the

[12] M.S.A.E.—Sales promotion manager, International Motor Co., Long Island City, N. Y.

[13] M.S.A.E.—Engineering division, refined oil department, Vacuum Oil Co., New York City.

operator that will work out toward that final result. It is, rather, a mutual discussion all the way through.

MR. SMITH:—I believe we are headed in the wrong direction when we begin a comparative cost-study of various types of motor-vehicle in the service of various companies. I am opposed to this, the reason being that every operator has many different conditions to meet, and for each condition he should study the available equipment and select that which meets the conditions. I do not believe that the Society should sponsor a comparative study of the excellence of different companies' products and make a decision as to what everybody ought to buy. That is entirely a matter for the individual companies to consider and to decide the matter upon the basis of their best judgment on the subject and the best advice they can get by talking to different people about their results. In that way some comparative data would be obtained which might possibly bear upon the individual case which they have in mind. I think it would be entirely out of order for any S.A.E. Committee to develop costs leading to the standardization or recommendation of one kind or group of vehicles.

MR. PIERCE:—I did not intend to have the idea conveyed that we were going to pick out any particular make. That would not be a good business policy. My motion was to compare the costs between the two systems, because I believe any company would be very reluctant to give out figures on individual makes of truck. I do not believe that would be fair. Nevertheless, the cost of those different makes of truck would travel by word of mouth and would benefit the manufacturer in the end.

MR. SMITH:—I still believe that we cannot get an answer unless we consider all the facts. If we are to get an answer that is worth anything, we have to go to the bottom of the problem. That means considering every factor that goes into it, and one very important factor is the adaptation of the vehicle to the type of service. If we are to get a comparison, we might as well do a real job. I think the Society is not the proper organization to do it.

ACTING CHAIRMAN BEECROFT:—Do you favor a continuation of the subject and a comparison of the two systems?

MR. SMITH:—Yes.

ACTING CHAIRMAN BEECROFT:—Are you ready for the question? Those in favor of a continuation of the study of the two systems say "aye"; contrary-minded "no." It is carried.

Summary by Mr. Middleworth

MR. MIDDLEWORTH:—One of the most important points brought out in the discussion seems to be the necessity for each individual fleet operator to make a careful and thorough survey of the conditions under which he operates before deciding how his fleet shall be maintained. I do not think it possible to make any set rule which would be applicable or meet the requirements of all operators. Mr. Brede states that he believes that the correct answer to the problem is a combination of both systems, and I am inclined to agree with him.

With reference to the question asked by Mr. Alden, "What efforts are made as to penalties against drivers, or to apply to the bonus and honor systems for freedom from accidents?" our company established a traffic court of inquiry about three years ago. The court has a miniature set-up of streets, buildings, automobiles, street-cars, pedestrians, and so forth made to scale. With this equipment we are able to reproduce the street conditions at the time the accident occurred. The drivers are brought before the court and asked to place these models upon the miniature street in the same position they were in when the accident occurred. We have found in many instances that the description in the accident report is erroneous. We then get at the facts and endeavor to suggest a means of preventing a future similar accident. If we find a driver has had too many accidents, we recommend that he be reprimanded, punished or dismissed. We believe this is one of the best means of preventing accidents.

In reviewing the discussion prepared by Captain Thee[14], I am not wholly in accord with his statements concerning the lack of progress made in the economical and efficient methods employed in the maintenance of motor-vehicles. To be sure, it is reasonable to admit that the methods of production of motor-vehicles as regards economy and efficiency may have progressed more rapidly than methods employed in the maintenance of motor-vehicles; but it does not seem reasonable to presume that maintenance of motor-vehicles has been "stagnating" during the last 10 to 15 years. Many operators' as well as manufacturers' service-stations have been constantly adopting new and improved methods which have not only speeded up the work, but have shown an economic improvement over former maintenance methods. Many have learned to use previously repaired major-units—that is, replacement units—rather than hold up the job awaiting the repair of the unserviceable unit removed from the chassis, thereby effecting a substantial saving in time out of service. Many special time-saving tools and fixtures have been installed, and many labor-saving devices have been placed in operation.

During the last 10 years there has been a decided improvement in the preparation of motor-vehicles for repainting, and a very marked improvement in the methods employed in the application of paint to motor-vehicles. This not only effects a saving in time out of service, but a substantial saving in the cost of labor. The system of maintenance employed by the United States Army may work out advantageously for its particular requirements, but I cannot see how such a system could be applied to the maintenance methods of either a small-scale operator or a large-scale operator.

Captain Thee suggests that "perhaps the ideal solution for the adoption of the unit-replacement system by fleet operators is not to buy vehicles complete, but to purchase units and build the vehicles with them." Such a program might apply to the United States Army, due to the specialized service in which the vehicles are to function, but if even the large-scale operators were to adopt such a program, the motor-vehicle industry would be seriously affected. Further, it does not seem reasonable to suppose that motor-vehicles can be built by the methods suggested either as efficiently or as economically as they are now built by the manufacturer.

That part of Captain Thee's discussion relating to factory service-stations carrying a reserve stock of rebuilt units for replacement seems ideal. This would enable the operator to exchange an unserviceable unit for a serviceable unit at probably less cost than if the unit were rebuilt in his own shop.

[14] See S.A.E. JOURNAL, August, 1930, p. 210.

Development of a Safe Airplane

Discussion of T. P. Wright's Detroit Aeronautic Meeting Paper[1]

IN May, 1927, the Daniel Guggenheim Fund for the Promotion of Aeronautics announced its Safe-Aircraft Competition, and on Jan. 1, 1930, the first prize in that Competition was awarded the Curtiss Tanager airplane that had been entered by the Curtiss Aeroplane & Motor Co., Inc. What transpired in the intervening 31 months is revealed in the paper, which deals with the research, design and development work of the Curtiss engineers.

The theoretical calculations that were first made showed that no existing airplane could possibly meet the rules and that the speed range could be met by using slots and flaps in conjunction with a good basic section. The work done in the wind-tunnels to determine the most advantageous design of slots and flaps and their specific application to a medium high-lift wing-section, the Curtiss C-72, is described. This resulted in a combination of front and rear slots and a floating aileron.

Considerations of necessarily large wing-area accompanied by small unit-weight dictated the selection of a biplane wing-arrangement with an overhung upper panel. Resistance and practicability eliminated the open cockpit in favor of a cabin fuselage with bulged sides that faired in well with the radial air-cooled engine, the Curtiss Challenger, that was selected as the powerplant. Landing-gear and tail-skid design received very careful consideration that resulted in the choice of a large-stroke oleo shock-absorber for both. The slot mounting, flap control and floating-aileron control were the most interesting features from a mechanism-design standpoint and these are described. No new types of construction were developed in the design of the structure, although every part was refined as much as possible to save weight.

Data on the types of construction and the materials used are presented, with numerous illustrations of the various units. Emphasis naturally is placed on the safety features of the airplane, such as slow speed of flight, slight likelihood of striking the ground in any but a normal attitude, freedom from any tendency to fall off to one side when in stalled flight, inability of experienced pilots to make the airplane spin, a steep angle of climb and the elimination of using the rudder for normal flying and turning maneuvers.

A brief description of the flight tests made by the company's pilots between Oct. 12 and 29, 1929, is given. In these tests the only changes made were lengthening the stabilizer-adjustment screw and modifying the cowling and propeller, these being done to secure a slightly more favorable performance. The tests conducted by the Guggenheim Fund pilots were divided into three groups—qualifying, safety and Competition rating tests—all of which were satisfactorily passed by this airplane alone.

Among the points brought out in the discussion were that the airplane in coming out of a dive puts its nose down slightly, the only special feature about the landing gear is the increased oleo stroke which is approximately double the usual practice, movement of the rudder is not necessary in going into a bank and that the difficulty of flying an airplane will be very largely diminished, if not almost entirely eliminated, when an airplane is produced in which coordination of control is not necessary to avoid serious trouble.

J. T. HARTSON[2]:—Into how steep a dive will the airplane go when the power is cut off and the elevators pulled back suddenly? From a stalled position, into how steep a dive does it go in regaining flying speed? Does it squash out of it, or does it put its nose down?

T. P. WRIGHT:—It puts its nose down slightly, but not below horizontal. One of the Competition tests was the requirement that the airplane recover within 250 ft. by using the controls from any maneuver or any attitude in which it would be placed or automatically without resorting to controls within 500 ft. In carrying out the test, the airplane, from a fairly high speed, was pulled up into almost vertical stalling attitude, the rudder was kicked hard over and the controls released, which let the airplane fall off in the direction that the rudder indicated. I do not know the actual speed, but I do not think it could have been more than about 60 m.p.h. to recover in 500 ft. as we did, and with the use of the controls the airplane could be pulled up in absolutely no time.

MR. HARTSON:—If, in coming in for a landing, the engine stops for some reason or other, the average instinct is to pull the stick back, and I am wondering whether it would nose in.

MR. WRIGHT:—That can be done without any serious results. That was the test spoken of in the table that Lieutenant Umstead made. You will notice from the results of the speeds, that the airplane flies considerably slower with the power on than with the power off. It flew at 30 m.p.h. with the power on and at 37 m.p.h. with the power off. He flew it with the power on, which would be at 30 m.p.h., about 30 ft. from the ground, and then cut the gun suddenly, holding the controls all the way back as they were, which meant that it was 7 m.p.h. before stalling speed with the power off, and the ship nosed down a little and made a perfectly satisfactory landing. In this test the airplane noses down but never below level-flying position. No matter how close to the ground this is done, the airplane makes a satisfactory, but possibly hard, two-point landing.

MR. HARTSON:—Suppose he had done that with power at 100 ft.?

MR. WRIGHT:—I believe that it would have been all right. I cannot say that it actually was done, but I would not be at all fearful of seeing it attempted. This was done repeatedly at 25 ft. in the 500-ft. square test.

[1] The paper was published in the May, 1930, issue of the S.A.E. JOURNAL, p. 543. Mr. Wright is a Member of the Society and chief engineer, airplane division, Curtiss Aeroplane & Motor Co., Inc., Garden City, N. Y. The abstract that preceded the paper when it was published is reprinted for the convenience of the reader and is supplemented by a brief summary of the discussion.

[2] Sales manager, Comet Engine Corp., Madison, Wis.; now Air Associates, Inc., New York City.

The airplane took off under full power and with the controls held full back. It kicked around the turn and the power was cut off with the controls always full back.

Long-Stroke Oleo and Other Features of Design

GERARD VULTEE[3]:—I have read several articles about a long-stroke oleo being used, and I would like to know the approximate length.

MR. WRIGHT:—As I recall it, the stroke was either 11 or 12 in., and I think the wheel travel was about 14 in.

M. B. KARR[4]:—Were not some features incorporated in the landing-gear design that might be of value to the industry as a whole?

MR. WRIGHT:—This landing gear was entirely conventional. The only special feature about it was the oleo stroke, which was approximately double the usual practice, and the arbitrary increase in the load factor which we used in this design was, I judge, approximately 8 instead of 6. This was necessitated by the more rapid vertical descent of the airplane than is common practice, this airplane hitting the ground at a velocity about 50 per cent greater than normal airplanes. The actual design was merely chrome-molybdenum steel tubing throughout, with no special feature other than the long stroke and the higher load-factors.

MR. HARTSON:—What is the vertical velocity of the airplane when it glides with the flap down and the stick back?

MR. WRIGHT:—The angle was 13 deg., and the forward speed was 40 m.p.h. That was the biggest surprise we received. We thought that the ship would descend at a far greater angle than 13 deg., and it appeared to do so. I believe anyone who witnessed the test would say that the ship was coming down at about 30 deg., but the angle actually was 13 deg.

GEORGE J. HIGGINS[5]:—Somewhere about 9 or 9.5.

MR. WRIGHT:—The 9, actually 8½, would be the speed in miles per hour, which is 13, actually 12½ ft. per sec. I think the rate of the Autogiro is slightly higher, about 16.

Aileron Movement in Turning

RALPH H. UPSON[6]:—Will Mr. Wright give a little more detail as to the procedure and action in making what is for this airplane apparently a normal turn with the ailerons? Does a certain amount of side-slipping take place to produce the result? Also how far do the ailerons have to be reversed again to keep from getting an excessive bank?

MR. WRIGHT:—In so far as going into the bank is concerned, having talked with a number of pilots and made two or three flights myself, I can assure you no rudder movement is necessary. We can throw the stick any distance to give the turning moment, and the ship will automatically take the correct angle, so that no slipping or skidding will occur, leaving the rudder absolutely neutral. The reason for that, of course, is the fact that the ailerons give not only a neutral but in certain angles a positive yawing movement in the right sense. Of course, we have to pull the stick back as the bank gets steeper, but in so far as the rudder is concerned, we can fly without any recourse to the rudder.

Now, as to the amount of reverse aileron movement when we get to the angle at which we want to turn, I am sorry I cannot answer that, because I did not have the experience myself nor did I ask anyone.

MR. HARTSON:—I believe that the chief problem in learning to fly is that of coordination of control, to coordinate rudder and aileron, and this is the only medium of transportation requiring that coordination. Do you think it possible, from your experience, to have an airplane without a rudder?

MR. WRIGHT:—That is a point on which we probably debated many hours more than on any other. The idea that we could do away entirely with the rudder on a ship such as this has a number of proponents. Of course, that would not permit of coming in with a side slip and killing speed by this method. Personally I do not believe that the rudder can be eliminated for some time. Perhaps it can eventually be abandoned, but I believe it will be retained for possible use.

I do not know how landing in a side wind without the rudder would be. Perhaps it would not be possible, but airplanes that have not had rudders, such as the Burgess-Dunn, are tremendously stable. I do not believe they are in general as satisfactory in cases of certain kinds of maneuvering as those that have a rudder but the important point is that, in so far as a step to a fool-proof airplane is concerned, I think that the ability to not abuse the rudder, as can be done with the Tanager, is an extremely important point. I do not doubt that pilots of far less ability can, with absolute safety, fly the Tanager.

We made a demonstration with one of our engineers who had never flown an airplane, as we thought no particular risk was involved. We let him take the airplane off, fly it around the field and land, and although he is a good engineer, he had never flown before. With just about that amount of piloting ability, I also flew the airplane and landed it without any trouble.

In landing the Tanager, we merely have to hold the stick all of the way back and wait for the airplane to hit the ground, because it will not nose over and any lateral control that we want at that slow speed is absolutely present. We can move the control stick along here for lateral control, all of the time holding it all of the way back; so I really think that as far as a dub pilot flying with safety is concerned, we have taken a long step forward.

PRESIDENT E. P. WARNER[7]:—The problem, as I see it, in flying is not the coordination of control. That is an old story. In a sense we do not have it in any other vehicle, but we have it in many other daily activities. Anyone who plays golf knows how to coordinate his muscles, or else he does not hit the ball, and if we can get all of the golfers to flying airplanes, we will have a pretty good business. In golf, if we do not coordinate, we miss the ball, but if we do not coordinate when flying an airplane something worse will happen.

The mental hazard of some dire consequence of improper coordination is what we are concerned with, and when we produce an airplane, which I understand the Curtiss Company believes it has produced in the Tanager, in which we can coordinate properly or improperly, or badly or not at all and still not get into serious trouble, the difficulty of flying an airplane will have been very largely diminished if not almost entirely eliminated, but we will still try to coordinate the control properly.

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[3] M.S.A.E.—Chief engineer, Lockheed Aircraft division, Detroit Aircraft Corp., Detroit.

[4] Metallurgical Laboratories, Philadelphia.

[5] Associate professor of aeronautical engineering, University of Detroit, Detroit.

[6] M.S.A.E.—Aeronautic engineer, Red Bank, N. J.

[7] M.S.A.E.—Editor, *Aviation*, New York City.

Geared Centrifugal Superchargers for Airplane Engines

Discussion of Dr. Sanford A. Moss's Detroit Aeronautic Meeting Paper[1]

IN a written discussion submitted by Arthur Nutt the points brought out were that supercharger construction is responsible for more complicated accessory-drive housings, whether the distribution in a supercharged engine is any better than in an unsupercharged engine with a suitable manifold, using a supercharger to obtain satisfactory mean effective pressure with slightly less weight than was possible with a multi-barrel carbureter and that, if the supercharger can be eliminated from a commercial engine without too great a sacrifice in performance, that engine will be a better engine without the installation of a supercharger.

High points brought out in the oral discussion were that the diffuser and impeller curves must be very accurate, no more power is required to drive a supercharger than for the same degree of compression in the engine cylinder itself, using a supercharger to overcome a poor intake design is not good practice and a good supercharger is one that is very reliable and absorbs no power until the pilot needs excess power.

ARTHUR NUTT[2]:—After reading Dr. Moss's paper on geared centrifugal superchargers for aircraft engines, I believe that a number of points would be worth considerable discussion. As far as the history of the geared-drive supercharger is concerned, it dates back to 1917 when a partly built-in supercharger was ordered by the Curtiss Aeroplane & Motor Co. for installation on the Curtiss K-12 engine. This supercharger consisted of a case and impeller designed to attach to the anti-propeller end of the engine and was driven by a long shaft through the center of the engine V which was in turn geared to an internal gear cut on the inside of the large reduction-gear. A friction clutch was inserted in this long shaft near the propeller end to eliminate all possibility of torsional or accelerating forces being transmitted to the supercharger.

Of the four of these outfits originally designed and ordered, the first two were requisitioned by the Air Corps for experimental work at McCook Field, the third and fourth units being delivered to the Curtiss Company. The development work on this supercharger did not progress rapidly because more effort was being placed on improving the engine itself than on the development of a supercharger. As a result, very little information was obtained from this unit, which was found later to be very weak structurally, not being able to withstand any kind of backfiring. It had, however, most of the essential design features of the present-day supercharger. This engine was the first in the United States, as far as I know, to be equipped with a gear-driven centrifugal-supercharger and not until 1924 was a radial engine, Curtiss 400-hp. R-1454, built with the gear driven supercharger similar to those now used.

Distribution in a Supercharged Engine

Dr. Moss states that in the use of a built-in supercharger none of the complication of separate paths through independent carbureter barrels to separate banks of engine cylinders is encountered as often occurs with unsupercharged engines. Unfortunately, this leads one to believe that to incorporate the built-in supercharger in a crankcase of an engine would be simpler than to use the conventional induction-system. In actual practice engines with superchargers built in have very much more complicated accessory-drive housings for which the supercharger construction is directly responsible. This is a particular hardship on engines of low power with a few cylinders from a cost and maintenance standpoint. We must also bear in mind that the V-type of engine requires the same kind of manifold either with or without a supercharger. This is necessary since, as soon as the engine reaches the altitude at which it delivers sea-level power, the manifolding must, from then on, function the same practically as an engine without a supercharger. Therefore, the manifold must be designed to distribute properly the gas without the aid of the heat of compression from the supercharger which is present at sea level. For example, the gallery type of manifold which has been used in the past on V-engines does not give satisfactory performance at all altitudes. No manifold should be put on an engine that would not distribute properly without a supercharger if it can be avoided.

Regarding the improvement in distribution, I doubt very much whether we can say that the supercharged engine has any better distribution than an unsupercharged engine with the proper manifold, and many engines today have good manifolds that give extremely low specific fuel-consumption. For example, the Curtiss D-12 engine has been run on as low a specific fuel-consumption as 0.39 lb. per b.hp-hr. at full throttle which would not have been possible without good distribution. In the construction of radial engines or any engines with accessories combined with a supercharger as shown in Fig. 1 a number of shafts for driving accessories must be brought through the diffuser. The introduction of such interferences in the diffuser section has been known to create sufficient disturbances to cause very poor distribution so that in my opinion improving distribution by means of the supercharger is not always

[1] The paper was printed in the August, 1930, issue of the S.A.E. JOURNAL, p. 148. The author is connected with the Thomson Research Laboratory of the General Electric Co., West Lynn, Mass. A brief summary of the discussion is presented herewith for the convenience of the reader, but the abstract that preceded the paper when it was published has not been reprinted.

[2] M.S.A.E.—Chief engineer, motor division, Curtiss Aeroplane & Motor Co., Buffalo.

possible. In view of these facts we should not assume that the supercharger will improve the smoothness in running of an engine unless a proper distributing system is also used on this engine, and I consider that the passages through the diffuser and to the cylinders are all included in this distributing system.

Cost versus Weight

On multi-cylinder radial-engines with seven or more cylinders, the centrifugal supercharger enables the designers to obtain satisfactory mean effective pressure with slightly less weight than could be obtained by the use of multi-barrel carbureter and separate passages. The use of the supercharger, however, introduces extra cost as very great care must be exercised in the manufacture of gears, bearings and all parts having to do with the operation of this high-speed unit, the impeller of which runs between 10,000 and 30,000 r.p.m., depending on the amount of supercharging desired. Therefore, in selecting the design for the carburetion system on an aircraft engine very careful study of the consideration of costs versus weight and performance versus reliability is essential. The day is rapidly nearing when the time between overhauls will not be measured by a few hundred hours and the experience that will be built up in the next few years will teach the operator whether it pays to incorporate the extra parts required for supercharging both from a cost standpoint as well as a reliability standpoint. If the performance and weight can be sacrificed to permit the engine to give very much more service and reliability, an attempt to eliminate the extra complication of the cost of supercharging would then seem advisable. However, if the supercharger proves to be able to run as long as any other part of the engine, continuing to use it commercially will then be advisable. Unquestionably the use of the supercharger for military purposes is not only desirable but essential. The supercharged engine for military purposes is 0.3 to 0.4 lb. per b.hp. lighter at its rated altitude than an engine without a supercharger but with a very high compression-ratio, both engines being rated at the same normal crankshaft-speed. With proper fuel the supercharged engine can be boosted at sea level to give at least 20 per cent more power than can be obtained with a high-compression engine at full throttle with the best fuel obtainable.

The supercharger may also be found essential on commercial-aircraft engines where they are used at great altitudes. I have not discussed the exhaust-driven supercharger owing to the fact that it does not appear to be a practicable commercial application and, contrary to Dr. Moss' statement, I believe the use of this type of supercharger has been and will continue to be very limited on account of its complication and the inaccessibility that it gives to the powerplant. One of the first requirements of the commercial engine is that it be extremely accessible. This applies particularly to the engine that is to be used in regular transportation, inasmuch as maintenance costs are very largely controlled by this factor.

By adding a supercharger very astonishing performance can be obtained from an unsupercharged engine of a design that gives high volumetric-efficiency. An engine, however, originally designed for a supercharger may have an inefficient intake-manifold and cylinder design that the supercharger overcomes at the expense of heating the charge and the use of more power to drive the supercharger. These losses are no doubt small but the difference between a good engine-design and a poor one lies in these small losses which are only found by development and experience. Dependence on supercharging to overcome bad design must be avoided carefully and is difficult to check since an engine designed with a built-in supercharger cannot usually be run without the supercharger and mean anything.

In general, if the supercharger can be eliminated from the commercial engine without sacrificing too much performance even at the expense of some added weight, that engine would be a better engine without the supercharger, although this statement cannot be too broad inasmuch as each engine must be discussed by itself as far as the application of a supercharger to it is concerned, depending on the type of engine and the kind of service to which the engine is to be subjected. For example, we may say that if a military engine is a good engine unsupercharged, it is a better military engine supercharged, but this statement does not apply to commercial engines necessarily.

C. F. TAYLOR[3]:—Dr. Moss' remarks on the improvement in distribution resulting from the use of a supercharger are very interesting. Actual quantitative data seem to be entirely lacking on this subject with the exception of some tests that were run at M.I.T. and reported upon in a paper[4] that I presented at the Semi-Annual Meeting in 1929. The results reported in that paper indicated that a centrifugal supercharger does effect an appreciable improvement in distribution at or near full engine-load and that this effect becomes almost negligible as soon as the load is considerably reduced. Unfortunately, these tests were made on a supercharger that was not equipped with diffuser upon which Dr. Moss counts so heavily for the vaporization effect. Tests on the diffuser type of supercharger have not been made at Technology on account of the expense of this type of equipment. Fortunately we now have a General Electric supercharger with diffuser and hope to make some quantitative experiments to determine its effect on vaporization as distinct from its effect due to the increase in pressure and temperature.

F. E. FICK[5]:—Has Dr. Moss ever successfully used these superchargers for charging cylinders on two-cycle engines?

DR. SANFORD A. MOSS:—An appreciable use of centrifugal superchargers on two-cycle engines has been made, principally in Europe, with a limited use in the United States.

MR. FICK:—Centrifugal superchargers?

DR. MOSS:—Yes. The centrifugal supercharger at low engine-speed during starting gives low pressure, but the resistance against which the charge is to be forced at low speed is also proportionately very low. Theoretically the friction loss is in proportion to the square of the speed, and the pressure rise of the centrifugal supercharger is in proportion to the square of the speed, so that theoretically the supercharger is just as available in overcoming friction at low speed as at high speed. This was proved to be the case by the Junkers engineers. A recent paper[6] by the Junkers engineers in Europe substantiates this point, that a two-cycle engine with a cen-

[3] M.S.A.E.—Professor of aeronautic engineering, Massachusetts Institute of Technology, Cambridge, Mass.

[4] See S.A.E. JOURNAL, July, 1929, p. 49.

[5] M.S.A.E.—Chief engineer, Western Reserve Air Motors Corp., Lakewood, Ohio.

[6] See *Diesel Power*, February, 1930, p. 91.

trifugal supercharger operates equally well at starting as at full speed.

Accurate Diffuser and Impeller Curves

R. S. LIVINGSTONE[7]:—Why must the curve of the impeller passage be figured with such extreme precision? Dr. Moss mentioned that this curve must be exactly right, as a result of very close computation, I believe.

DR. MOSS:—I alluded to the diffuser curves. The impeller curves themselves must be given some attention but mainly as a matter of easy machining. The fluid flows out of the impeller into the diffuser at a very high velocity and must be slowed down so that the velocity will be converted into pressure. To have the fluid shoot through a diffuser without slowing down is easy, and then we get no pressure rise or conversion.

HAROLD CAMINEZ[8]:—Dr. Moss made some remark about the efficiency of the centrifugal compressors being approximately 70 per cent. He did not state whether that is the mechanical efficiency or the ratio of the useable energy in the air after it is compressed to the power required to drive the supercharger. From my experience the efficiency of these devices is not very high; the 70 per cent efficiency that Dr. Moss mentions is the efficiency compared with adiabatic compression. How would the efficiency of a good air-compressor compare, on the same basis, with that of the supercharger?

DR. MOSS:—This efficiency is the over-all efficiency. I know that Mr. Caminez has had considerable experience with different kinds of supercharger that did not have good efficiency. Displacement machines have several different kinds of efficiency; what is known as volumetric efficiency, which is the ratio of the actual cubic feet of air delivered to the displacement, and over-all efficiency, besides the mechanical efficiency which is the ratio of the power put into the gears to the power actually delivered to the impeller. I am talking about the over-all efficiency. Many tests on centrifugal compressors which are sold under guarantee of performance show 70 per cent efficiency as an average figure and 75 per cent as frequently obtained.

A. H. PACKER[9]:—Is the tendency to use superchargers on airplanes in commercial-transport service increasing?

DR. MOSS:—All airplanes in transport service have superchargers.

CHARLES A. MORSS[10]:—Dr. Moss stated that the Wright J-6 engine, supercharged 8¾ to 1, has a pressure corresponding to about a 20 per cent increase in air charged per cylinder. Nevertheless, if we compare the actual power at sea level of the Wright J-5 engine and the Wright J-6 seven-cylinder engine, making allowance for the difference in the rated speed and the slight difference in the cylinder displacement, we will find that their powers are similar. In other words, apparently all the power that is gained by supercharging goes into driving the centrifugal supercharger. I would like Dr. Moss to tell us how much power is required to drive that supercharger.

[7] Promotion manager, Thompson Products, Inc., Cleveland.

[8] M.S.A.E.—Engineer in charge of aircraft-engine department, Allison Engineering Co., Indianapolis.

[9] M.S.A.E.—Copy writer, Williams & Cunnyngham, Chicago; now Dyer-Enzinger Co., Inc., Milwaukee.

[10] M.S.A.E.—Army Air Corps, Wright Field, Dayton, Ohio; now experimental test engineer, Wright Aeronautical Corp., Paterson, N. J.

[11] Assistant chief engineer, Allison Engineering Co., Indianapolis.

Power Required to Drive Supercharger

DR. MOSS:—In the first place, the power required to drive the supercharger is no more than that necessary for the same degree of compression in the cylinder itself, taking account, of course, of the engine efficiency. The first stroke in a four-cycle engine is a compression stroke, and it gives a certain amount of compression with a certain efficiency, bearing in mind the engine friction. The centrifugal supercharger has equal efficiency.

A comparison of the J-5 and J-6 engines, which was cited, will, if carefully made, show that the latter has more power with wide-open throttle. We must not forget, of course, that the entire amount of supercharging is not available for actual increased power above sea level, because in some cases, as Mr. Nutt pointed out, some impairment of efficiency occurs because loss in the intake and the carbureter passages has occurred due to their being too small. Some engineers have used superchargers to overcome that disadvantage. To have a poor intake and use a supercharger to overcome it is not the proper procedure. If that is done, we have a loss of power. If we are careful to have full-sized passages, so that we do not have to waste any power in overcoming this condition with a supercharger, then we get the increased power that is specified, as careful tests of the mean effective pressure show.

JOHN L. GOLDTHWAITE[11]:—Dr. Moss stated that supercharging not only the displacement but also the clearance was possible. I do not altogether understand how with the two valves in the head of the engine he is able to scavenge the clearance space without sweeping much of the fuel mixture out into the exhaust. That is the major problem in the two-cycle engine. How can it be accomplished in a four-cycle engine where the valves are not designed to stratify the charge?

DR. MOSS:—I do not know how it is done, but the fact is that a good supercharger will add more power to the engine, than corresponds to merely increasing the displacement, so that the only way to explain it is to say that the clearance space was scavenged. Of course, currents in the engine can be induced between the inlet and the exhaust valve. The charge shot into the clearance passage through the inlet valve does not necessarily go out through the exhaust valve.

MR. CAMINEZ:—Centrifugal supercharging only became popular with the advent of the radial engine, because with that engine the induction problem is very difficult. In in-line engines, for which supercharging was first developed, the devices do not appear from actual use to be as satisfactory. As Mr. Nutt pointed out, the distribution problem is not helped much by supercharging. The manifolding with supercharging is very difficult with an in-line engine. In early experimental work at McCook Field a gear-driven supercharger was used on the air-cooled Liberty engine and under certain weather conditions this engine was very poor from the standpoint of distribution.

Fuel Consumption of Supercharged Engines

I notice that Dr. Moss states the only in-line supercharged engine was the Wright 12-cylinder inverted. I wonder if he could give any specific data as to the fuel consumption of this engine, as to how it compares with the Curtiss D-12 that does not have centrifugal

charging, whether the specific fuel-consumption is any better or worse, because such information would be more specific and would give us engine designers better ideas as to the merits of supercharging.

DR. MOSS:—I can give no such specific data. However, Curtiss D-12 engines are being supercharged to an appreciable extent. Mr. Nutt points out that these engines are being supercharged as much as 20 per cent at sea level. One Curtiss in-line engine, the Superconqueror, has a geared centrifugal supercharger. The results have not been published, but I believe Mr. Nutt will have some data shortly. However, no extensive use of centrifugal superchargers in in-line engines is being made at present, and what will happen will be disclosed in next year's work. We are glad, of course, to have supercharger business from the radial engines. Whether the in-line engines will displace the radial or whether centrifugal superchargers will be used then I do not know.

GEORGE W. LEWIS[12]:—I remember that in 1918, when I went out to McCook Field, we certainly did not know much about supercharging and the effect on the engine. I remember one of the first tests on the Liberty engine which worked fairly well until Dr. Moss put the supercharger on and then, with the breaking of the spark-plugs, it looked as though we were popping corn. After that the engine and the supercharger were taken to Pike's Peak to find out exactly what it would do at altitudes. Of course, the following year the altitude chambers at the Bureau of Standards were built so that we could study accurately the effect of supercharging. Supercharging will play a very important part in aircraft-engine development, because if we have a given engine at given power, we can increase that power for less weight by supercharging than by any other means. The ideal supercharger, of course, would be one that is very reliable and absorbs no power until we need it. When we need the excess power we throw in the supercharger and get it. We want power. We want economy. We want reliability.

Some investigations are being carried on at present to find out just what effect supercharging will have on compression ratios such as 4, 4.5, 5, 5.5 and 6. We may be able to obtain better economies at those low compression-ratios by proper means and also use a supercharger so that we can get the excess power and still get that inherent reliability in an engine that has a low compression-ratio.

In back of every successful engineering endeavor we will always find one man, and in this particular case we find Dr. Moss, because he certainly has stuck to the centrifugal-type supercharger and brought it through in a very excellent manner. The industry is to be congratulated not only on having a source of design information but also on obtaining one of the best possible superchargers for either radial or in-line engines.

[12] S.M.S.A.E.—Director of aeronautical research, National Advisory Committee for Aeronautics, City of Washington.

Aircraft-Engine Installation

(*Concluded from page* 273)

and, as they proved to be too effective in winter temperature, tin plates were put over the front to stop the flow of air through the coolers. In taking the southern route to California, I believe it would be necessary to remove these plates. When we reached Wichita, Kan., the oil in the three engines was rather warm, so we took the tin plates off and found we were lucky to get even a 10-deg. cent. (50 deg. fahr.) reading on the oil-temperature gages. I promptly put the tin plates back and left them on for the remainder of the trip.

Much can be done in using these oil coolers, especially the type we were using, if some kind of shutter is provided so that the temperature can be regulated. If trying to run on the assumption that the oil cooler regulates the temperature, one is likely to get frightened when the change one really gets shows up. One has the feeling that when the oil going to the engine is as low as 10 deg. cent. (50 deg. fahr.) it is entirely too cold. I recommend that some kind of shutter be put on the oil coolers. Of course, it is an added control for the pilot to worry about, but I think he would rather adjust a shutter than worry about oil temperature all the time.

ARTHUR LEAK[5]:—In experimenting with oil coolers with one of our engines which had a rather high temperature throughout, our experience has been that two types of cooling would operate satisfactorily. One consists in running a quantity of tubes through the oil tank transversely, the air being caught by an adjustable shutter and led through these tubes and out the other side. This seems to us the best arrangement where the airplane tank is in a suitable position and where there is room to do it. It simplifies the installation, but it cannot be done on all airplanes. With that in view we have also worked on the core-type radiator. By installing baffles in these oil coolers the oil is made to flow backward and forward, which increases the efficiency about 50 per cent. We had practically no luck with the core-type radiator cooler until we used baffles; but, with these fitted, they seem to work very efficiently. In regard to shutters, we have one which has to be operated by a butterfly valve from the cockpit. It is essential to use something of that kind, not only for flight but for warming up.

With reference to exhaust-gas-heated hot-spots, our principal experience has been with air-cooled engines. We have applied the heat above the carbureter, and found that there must be an elbow so that the gas impinges and gets the benefit of that heat; but, as Mr. Nutt says, it is necessary to have a temperature of about 350 deg. fahr. to obtain satisfactory results. Our present experience indicates that applying heat above the carbureter is a much better practice than heating before the air enters the carbureter, particularly from a distribution standpoint. The heat seems to be essential to secure smooth running and freedom from piston-ring trouble, particularly in cold weather.

[5] Curtiss Aeroplane & Motor Co., Inc., Buffalo, N. Y.

Effect *of* Weathering *on the* Vapor-Locking Tendency *of* Gasolines[1]

Semi-Annual Meeting Paper
Illustrated with Drawing and Charts

By OSCAR C. BRIDGEMAN[2] and ELIZABETH W. ALDRICH[3]

WEATHERING of gasoline occurs in fuel tanks, carbureter float-bowls and vacuum tanks of automotive equipment, the extent being dependent upon conditions of temperature and pressure. If there is sufficient fuel loss due to weathering, the vapor-locking tendency of the gasoline is reduced.

Experiments were made in laboratory equipment to determine the amount of loss and the decrease in vapor-locking tendency of a number of gasolines under various conditions. The factors varied were temperature, pressure, time and the size of opening to the gasoline container. In general it was found that there is very little loss until the vapor pressure of the gas-free gasoline exceeds the external pressure. When the vapor pressure of the gasoline exceeds the external pressure, loss occurs until the vapor pressure becomes equal to the external pressure if sufficient time is allowed for the vapors to escape through the opening.

In most of the experiments A.S.T.M. distillations were made on the gasolines before loss had occurred and on the residues after weathering. It was found that the A.S.T.M. temperature of the original gasoline, at a percentage evaporated corresponding to 10 plus the loss by weathering, was equal to the 10-per cent point of the residue. Since, with most gasolines, the vapor-locking tendency is determined by the 10-per cent point, a knowledge of the weathering loss permits an evaluation of the change in vapor-locking tendency on weathering. The loss may be computed from the temperature of weathering and the external pressure.

FLIGHT data obtained in airplanes climbing from the ground to altitude indicate that the temperture in the fuel tank remains considerably higher than the prevailing atmospheric temperature. Under these conditions of elevated temperature and reduced pressure, the fuel frequently boils in the tank, with resultant decrease in the vapor-locking tendency. Boiling of the gasoline indicates that the vapor-locking temperature at the existing pressure has been reached and trouble may be expected, particularly in those fuel systems employing a fuel pump. However, if trouble from vapor lock does not occur before the fuel commences to boil in the tank, it is probable that the weathering will automatically prevent the occurrence of vapor lock after boiling starts.

The present work was undertaken to determine the extent of weathering with a considerable number of gasolines under a variety of conditions and to evaluate the resultant change in the vapor-locking tendency of these fuels. The conclusion has been reached that there is no appreciable change in the vapor-locking tendency over the short periods of time involved until the vapor pressure of the gas-free gasoline exceeds the prevailing atmospheric pressure. When this occurs, the practical limit to the amount of loss by weathering and the change in the tendency to cause trouble from vapor lock can be quantitatively estimated for any given temperature and atmospheric pressure. The conclusions are also applicable to motor gasolines and to certain phases of the problem of evaporation loss on storage.

Apparatus and Procedure

The apparatus used in the weathering experiments is shown in Fig. 1. The container *A*, of brass, has a capacity of 1 liter and is used to hold the gasoline sample. It is closed at the top by a plug, *B*, 1 in. long, which is drilled to permit removal of the gasoline vapors. The plug screws into the top of *A* and the closure is made tight by means of a fiber washer. Container *A* is placed in the bath *C* containing water, the temperature of which can be maintained constant to 0.5 deg. cent. (1 deg. fahr.). The plug *B* is connected by means of rubber tubing to a line leading to the manometer *D* and to a vacuum pump. Four different plugs were available having openings 1 in. long and diameters of 1/8, 3/32, 1/16 and 1/32 in. respectively. The stopcock *E* is used to prevent loss during the period of time required to bring the temperature of the gasoline up to that of the bath *C*.

In making an experiment, the brass container *A*, together with the orifice plug, was weighed and then about 750 ml. (45.75 cu. in.) of the gasoline was introduced. The increase in weight gave the amount of gasoline used in the experiment. The temperature of the bath *C* was adjusted to the desired value, and the container, fitted with the appropriate orifice plug, was inserted in the bath. Connection was made to the line leading to the manometer and to the vacuum system, and the brass container was allowed to stand for 15 min., with the stopcock *E* closed, to permit the gasoline to attain the bath temperature. At the end of the 15-

[1] Publication approved by the Director of the Bureau of Standards of the United States Department of Commerce.

[2] S.M.S.A.E.—Research associate, Bureau of Standards, City of Washington.

[3] Junior chemist, Bureau of Standards, City of Washington.

min. period, the stopcock *E* was opened and the gasoline was subjected for a predetermined period of time to the desired pressure, which was maintained constant by observation of the manometer and adjustment of the valve *F*. The container was then removed from the bath and weighed again. The decrease in weight gave the amount of gasoline which had evaporated under the experimental conditions. The results were expressed as percentage loss by volume under each set of conditions by computation from the gravities of the original gasolines and of the residues. In most cases, A.S.T.M. distillations were made on the residues remaining in the container after weathering had occurred.

Data were obtained on 16 gasolines and blends, which are described in Table 1. Specification data on these fuels are given in Table 2, in which the distillation temperatures refer to the given percentages evaporated.

The factors varied in the weathering experiments were temperature, pressure, time during which weathering occurred, and size of orifice attached to the gasoline container. The results obtained in the study of the effect of these variables will be considered in the order named. The quantity of liquid in the container was not varied and a filling of 750 ml. (45.75 cu. in.) was used throughout in order to simulate conditions in which an airplane takes off with tanks almost full and then climbs to a given altitude and remains at that altitude for a given period of time. It is recognized that somewhat different values of the loss on weathering might be obtained for other initial quantities of gasoline in the container.

Effect of Temperature

It was concluded, *a priori*, that the amount of loss by weathering over a short period of time would be very small at temperatures below those at which the vapor pressures of the gas-free gasolines equalled the external pressure. Further, it seemed reasonable to assume that, when the gasoline was superheated, loss would occur until the vapor pressure of the residual gasoline equalled the external pressure at the temperature under consideration. To test these assumptions, a series of experiments were made with a number of gasolines in which the amount of loss by weathering was determined at a number of temperatures with every fuel, the other variables being maintained constant in each set. These data are shown in Table 3.

The next-to-the-last column represents the number of degrees centigrade by which the gasoline is superheated above the temperature at which its vapor pressure equals the external pressure. The amount of superheat in each case may be computed by means of the general vapor-pressure relation[6]

$$\log (p/760) = A\,[1 - T_{10\text{ per cent}}/T] \qquad (1)$$

where $A = 3.41 + 3.8 \times 10^{-3}\, T_{10\text{ per cent}} - 0.6\,\sqrt{S}$.
In this equation, p is the vapor pressure in millimeters of mercury, $T_{10\text{ per cent}}$ is the A.S.T.M. temperature in absolute centigrade degrees at 10 per cent evaporated, T is the temperature in absolute centigrade degrees corresponding to the pressure p, and S is the slope of the A.S.T.M. curve at 10 per cent evaporated expressed as temperature change in centigrade degrees per unit change in the percentage evaporated. For purposes of the present paper, A may be taken as 4.0 with sufficient exactness.

[6] See S.A.E. JOURNAL, July, 1930, p. 96.

TABLE 1—DESCRIPTION OF GASOLINES AND BLENDS

No.	*Source*[4]	*Remarks*
104A	Naturaline Co. of America	Natural gasoline aviation fuel
124A	Virginian Gasoline & Oil Co.	Natural gasoline aviation fuel
134A	Standard Oil Co. of California	Aviation gasoline
154	Standard Oil Co. of Indiana	Aviation gasoline
184	Atlantic Refining Co.	Aviation gasoline
194	Phillips Petroleum Co.	Natural gasoline aviation fuel
404	Richfield Oil Corp.	Aviation gasoline
S4	Bureau of Standards	1930 U. S. Motor gasoline
B4	Bureau of Standards	1930 Domestic aviation gasoline
C4	Bureau of Standards	50 per cent S4 and 50 per cent B4
384	Bureau of Standards	Propane blend with 124A (9 per cent loss)
394	Bureau of Standards	Propane blend with 124A (3 per cent loss)
704	Bureau of Standards	90 per cent 124A and 10 per cent grade-A natural gasoline
714	Bureau of Standards	80 per cent 124A and 20 per cent grade-A natural gasoline
804	Bureau of Standards	90 per cent 124A and 10 per cent benzene
814	Bureau of Standards	80 per cent 124A and 20 per cent benzene

[4] The gasoline contributed by the companies named are experimental samples and should not be considered as representative of their commercial products.

From equation (1) there are obtained, for the three pressures—760, 570 and 380 mm. (29.92, 22.44 and 14.96 in. respectively)—the following relations:

$$760 \text{ mm.} \quad t_{10\text{ per cent}} = t \qquad (2)$$

$$570 \text{ mm.} \quad t_{10\text{ per cent}} - t = 0.03\, t_{10\text{ per cent}} + 8.2 \qquad (3)$$

$$380 \text{ mm.} \quad t_{10\text{ per cent}} - t = 0.07\, t_{10\text{ per cent}} + 19.1 \qquad (4)$$

Equation (2), (3) or (4) was used to compute the temperatures in centigrade degrees at which the gasolines had the above vapor pressures. The differences between these computed temperatures and the tempera-

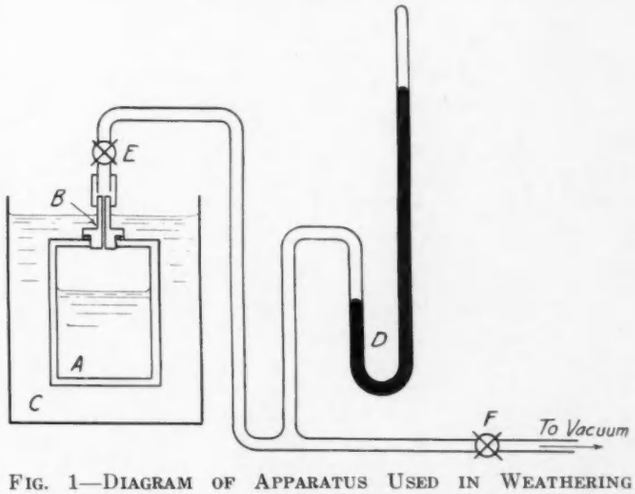


FIG. 1—DIAGRAM OF APPARATUS USED IN WEATHERING TESTS

A, Brass Container for Fuel Sample. *B*, Plug Drilled To Permit Escape of Vapor from Container. *C*, Bath Containing Water. *D*, Manometer. *E*, Cock To Prevent Vapor Loss During Time Required To Bring the Temperature of the Fuel Sample up to That of the Bath. *F*, Adjustable Valve To Regulate Pressure in Container *A*

TABLE 2—SPECIFICATION DATA ON GASOLINES AND BLENDS

Fuel	Temperature [a] 10 Per Cent Deg. Cent.	10 Per Cent Deg. Fahr.	50 Per Cent Deg. Cent.	50 Per Cent Deg. Fahr.	90 Per Cent Deg. Cent.	90 Per Cent Deg. Fahr.	Loss, Per Cent	Residue, Per Cent	60 Deg./60 Deg. Specific Gravity
104A	43	109	63	145	109	228	1.5	1.4	0.678
124A	69	156	76	169	109	228	0.5	1.5	0.691
134A	60	140	91	196	122	252	1.2	1.1	0.721
154	66	151	94	201	124	255	1.5	0.5	0.713
184	67	153	103	217	147	297	1.0	1.2	0.725
194	49	120	66	151	111	232	0.9	1.1	0.680
404	62	144	100	212	138	280	2.0	1.2	0.729
84	70	158	130	266	192	378	1.7	1.2	0.756
B4]	62	144	102	216	140	284	1.4	0.8	0.715
C4	69	156	115	239	176	349	1.0	1.2	0.737
384	42	108	76	169	107	225	9.2	1.4	0.688
394	65	149	76	169	107	225	2.7	1.3	0.685
704	66	151	76	169	108	226	0.7	1.4	0.690
714	61	142	76	169	108	226	1.2	1.3	0.688
804	69	156	76	169	106	223	0.7	1.4	0.705
814	70	158	74	165	98	208	0.7	1.3	0.736

[a] All temperatures refer to percentages evaporated.

tures of weathering are the amounts of superheat which are recorded in Table 3. The error introduced by taking A equal to 4.0 in all cases is less than 1 deg. cent. for the gasolines studied.

The values listed in the last column of Table 3 are computed data representing the maximum loss which would be expected on weathering at the given temperature and pressure. In obtaining these values, the 10 per cent temperatures of fuels, which in each case would have the desired vapor pressure at the temperature of weathering, were computed by means of equation (2), (3) or (4). Then, on the A.S.T.M. curve for each fuel, the percentages evaporated were read corresponding to the computed temperatures. By subtracting 10 from each of these percentages, the maximum-loss values were obtained. The reasons for using this procedure will be described in more detail later in the paper.

The figures given in Table 3 indicate that the loss which occurs on weathering during the short periods of time involved is very small up to the point at which the vapor pressure of the gasoline equals the external pressure, that is, until the gasoline is superheated. When superheated, however, considerable loss occurs, the extent being dependent upon the amount of superheat. In general, the observed loss is somewhat less than the computed maximum value. This presumably is due to the fact that the large volume of gasoline vapor which would be liberated cannot be removed through the small orifice in the time allowed. In these cases there probably is a considerable pressure gradient across the orifice, so that the external pressure on the gasoline is not that indicated by the manometer but is higher. In some extreme cases it was observed that

TABLE 3—EFFECT OF TEMPERATURE ON WEATHERING OF GASOLINES

Fuel	Temperature Deg. Cent.	Temperature Deg. Fahr.	Observed Loss, Per Cent	Superheat Deg. Cent.	Superheat Deg. Fahr.	Computed Maximum Loss, Per Cent
(a) Pressure, 380 Mm. (14.96 In.) of Mercury: Time, 15 Min.; Orifice, 1/8 In.						
104A	20	68	0.1	−1	−2	0
	30	86	8.1	9	16	19
	40	104	34.7	19	34	41
124A	50	122	2.8	5	9	35
	55	131	9.3	10	18	50
	60	140	35.0	15	27	60
	70	158	62.4	25	45	72
134A	40	104	3.1	3	5	3
	50	122	13.4	13	23	16
	60	140	25.1	23	41	30
154	40	104	0.5	−2	−4	0
	50	122	5.2	8	14	9
	60	140	18.9	18	32	24
184	40	104	0.4	−3	−5	0
	50	122	5.2	7	13	6
	60	140	15.8	17	31	17
	70	158	23.6	27	49	30
194	30	86	2.4	4	7	6
	40	104	15.8	14	25	37
	50	122	40.9	24	43	52
404	40	104	3.5	1	2	1
	50	122	8.6	11	20	8
	60	140	16.1	21	38	18
84	40	104	0.8	−6	−11	0
	50	122	3.6	4	7	2
	60	140	8.3	14	25	7
	70	158	10.6	24	43	13
	78	172.4	15.3	32	58	19
B4	25	77	0.2	−14	−25	0
	32	90	1.2	−7	−13	0
	41	106	4.0	2	4	2
	50	122	9.4	11	20	9
	60	140	16.0	21	38	18
	65	149	20.4	26	47	25
	68	154	22.0	29	52	29
C4	40	104	0.7	−5	−9	0
	50	122	3.8	5	9	4
	60	140	9.0	15	27	11
	70	158	12.1	25	45	20
	76	172	21.1	31	56	26
84	30	86	11.1	10	18	2
	40	104	14.4	20	36	8
	60	140	27.4	40	72	63
	70	158	52.3	50	90	74
394	20	68	0.8	−21	−38	0
	30	86	3.4	−11	−20	0
	50	122	11.7	9	16	35
	60	140	21.0	19	34	62
704	40	104	0.9	−2	−4	0
	50	122	7.2	8	15	37
	55	131	15.7	13	23	50
	60	140	27.0	18	32	59
714	35	95	0.9	−3	−5	0
	40	104	3.9	2	4	5
	50	122	11.7	12	22	36
	55	131	18.8	17	31	51
	60	140	26.6	22	40	60
804	40	104	0.3	−5	−9	0
	50	122	1.5	5	9	27
	60	140	13.2	15	27	64
	70	158	43.2	25	45	75
814	40	104	0.4	−6	−11	0
	50	122	1.5	4	7	43
	60	140	15.0	14	25	70
	69	156	47.8	23	41	79
(b) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 60 Min.; Orifice, 1/8 In.						
104A	20	68	0.6	−1	−2	0
	30	86	11.8	9	16	19
	40	104	37.8	19	34	41
(c) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 15 Min.; Orifice, 1/16 In.						
184	50	122	3.9	7	13	6
	60	140	14.8	17	31	17
	70	158	23.8	27	49	30
(d) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 60 Min.; Orifice, 1/16 In.						
104A	0	32	0.2	−21	−39	0
	30	86	12.0	9	16	19
	40	104	34.0	19	34	41
(e) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 15 Min.; Orifice, 1/16 In.						
184	50	122	4.4	7	13	6
	60	140	10.7	17	31	17
	70	158	22.9	27	49	30
(f) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 60 Min.; Orifice, 1/16 In.						
104A	30	86	9.9	9	16	19
	40	104	31.2	19	34	41
(g) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 15 Min.; Orifice, 1/32 In.						
184	50	122	2.8	7	13	6
	60	140	9.8	17	31	17
	70	158	14.7	27	49	30
(h) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 60 Min.; Orifice, 1/32 In.						
104A	30	86	10.7	9	16	19
	40	104	29.4	19	34	41
(i) Pressure, 570 Mm. (22.44 In.) of Mercury; Time, 60 Min.; Orifice, 1/8 In.						
104A	20	68	0.2	−13	−23	0
	30	86	0.2	−3	−5	0
	40	104	10.7	7	13	16

TABLE 4—CHANGE IN A.S.T.M. 10-PER CENT POINT ON WEATHERING

Fuel	Temperature Deg. Cent.	Temperature Deg. Fahr.	Loss, Per Cent	Residue 10 Per Cent Point: Observed Deg. Cent.	Observed Deg. Fahr.	Computed Deg. Cent.	Computed Deg. Fahr.	Difference Deg. Cent.	Difference Deg. Fahr.
(a) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 15 Min.; Orifice, 1/8 In.									
124A	60	140	35.0	73	163	75	167	−2	−4
134A	40	104	3.1	62	144	64	147	−2	−4
	50	122	13.4	71	160	73	163	−2	−4
	60	140	25.1	78	172	81	178	−3	−5
154	50	122	5.2	71	160	72	162	−1	−2
184	40	104	0.3	69	156	67	153	2	4
	50	122	4.9	71	160	72	162	−1	−2
	60	140	15.8	83	181	84	183	−1	−2
194	30	86	2.4	50	122	50	122	0	0
	40	104	15.8	54	129	56	133	−2	−4
	50	122	40.9	63	145	66	151	−3	−5
404	40	104	3.5	70	158	68	154	2	4
	50	122	8.6	75	167	75	167	0	0
	60	140	16.1	83	181	83	181	0	0
S4	40	104	0.8	71	160	72	162	−1	−2
	50	122	3.6	76	169	78	172	−2	−4
	60	140	8.3	84	183	87	189	−3	−5
	70	158	10.6	87	189	91	196	−4	−7
	78	172	15.3	94	201	99	210	−5	−9
B4	25	77	0.2	63	145	63	145	0	0
	32	90	1.2	65	149	64	147	1	2
	41	106	4.0	68	154	68	154	0	0
	50	122	9.4	74	165	76	169	−2	−4
	60	140	16.0	82	180	82	180	0	0
	65	149	20.4	83	181	87	189	−4	−7
	68	154	22.0	84	183	88	190	−4	−7
C4	40	104	0.7	71	160	71	160	0	0
	50	122	3.8	75	167	75	167	0	0
	60	140	9.0	81	178	83	181	−2	−4
	70	158	12.1	83	181	87	189	−4	−7
	76	172	21.1	93	199	97	207	−4	−7
384	30	86	11.1	67	153	68	154	−1	−2
	40	104	14.4	70	158	70	158	0	0
	60	140	27.4	72	161	72	161	0	0
	70	158	52.3	75	167	79	174	−4	−7
394	20	68	0.8	66	151	66	151	0	0
	30	86	3.4	67	153	68	154	−1	−2
	50	122	11.7	70	158	71	160	−1	−2
	60	140	21.0	71	160	72	161	−1	−2
704	40	104	0.9	66	151	66	151	0	0
	50	122	7.2	67	153	68	154	−1	−2
	55	131	15.7	70	158	70	158	0	0
	60	140	27.0	72	161	72	161	0	0
714	35	95	0.9	62	144	62	144	0	0
	40	104	3.9	63	145	63	145	0	0
	50	122	11.7	68	154	67	153	1	2
	55	131	18.8	68	154	70	158	−2	−4
	60	140	26.6	70	158	72	161	−2	−4
804	50	122	1.5	69	156	69	156	0	0
	60	140	13.2	71	160	72	161	−1	−2
	70	158	43.2	74	162	76	169	−2	−4
814	40	104	0.4	70	158	70	158	0	0
	50	122	1.5	70	158	70	158	0	0
	60	140	15.0	74	165	72	162	2	4
	69	156	47.8	74	165	76	169	−2	−4
(b) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 35 Min.; Orifice, 1/8 In.									
S4	70	158	13.8	94	201	96	205	−2	−4
	78	172	19.0	100	212	104	219	−4	−7
714	55	131	22.2	69	152	71	160	−2	−4
(c) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 45 Min.; Orifice, 1/8 In.									
C4	70	158	20.6	93	199	96	205	−3	−5
(d) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 60 Min.; Orifice, 1/8 In.									
104A	30	86	11.8	48	118	48	118	0	0
(e) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 60 Min.; Orifice, 1/16 In.									
104A	30	86	12.0	48	118	48	118	0	0
	40	104	34.0	57	135	59	138	−2	−4
(f) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 60 Min.; Orifice, 1/16 In.									
104A	30	86	9.9	50	122	47	117	3	5
	40	104	31.2	56	133	58	136	−2	−4
(g) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 130 Min.; Orifice, 1/8 In.									
B4	70	158	32.8	93	199	97	207	−4	−7
(h) Pressure, 380 Mm. (14.96 In.) of Mercury; Time, 175 Min.; Orifice, 1/8 In.									
814	60	140	49.2	76	169	76	169	0	0
(i) Pressure, 570 Mm. (22.44 In.) of Mercury; Time, 60 Min.; Orifice, 1/8 In.									
104A	30	86	0.2	45	113	43	109	2	−4
	40	104	10.7	48	118	48	118	0	0

the pressure could not be reduced immediately to 380 mm. (14.96 in.) on the suction side of the orifice but that several minutes were required before this could be accomplished.

TABLE 5—DISTRIBUTION OF TEMPERATURE DEVIATIONS

Temperature Deviation Deg. Cent.	Deg. Fahr.	Number of Points	Percentage of Points
5	9	1	1.4
4	7	8	11.8
3	5	5	7.5
2	4	19	27.9
1	2	12	17.6
0	0	23	33.8

Total Number of Points = 68
Grand Average Deviation = 1.5 deg. cent. (2.7 deg. fahr.)

The deviations between the observed and computed losses are much higher in the case of those fuels having flat distillation-curves, where a small change in the amount of superheat introduces a large change in the amount of loss which would be expected. With the propane blends—fuels 384 and 394—equation (2), (3) or (4) was used to compute the amount of superheat and the maximum loss. This is not accurate, for these equations do not hold for propane blends, but they were used in the present case to make the computed figures on these fuels comparable with those used for the other fuels. The inaccuracy of the relations for propane blends explains why the calculated losses at 30 and 40 deg. cent. (86 and 104 deg. fahr.) are much lower than the observed values in the case of fuel 384.

In most of the weathering experiments, A.S.T.M. distillations were made on the residues. The temperatures at 10 per cent evaporated read from these curves are shown in Table 4. A comparison of the distillation curves of the residues obtained by weathering at various temperatures with the distillation curve of the original fuel in each case revealed an interesting relation. The A.S.T.M. temperature, at a percentage evaporated corresponding to 10 plus the loss by weathering, was found to be equal to the A.S.T.M. 10-per cent point of the residue, within experimental error. The temperature obtained in this manner from the distillation curves of the original fuels, using the experimentally measured losses, are listed in the fifth column of Table 4. The differences between the observed and computed temperatures, shown in the last column, are seen to be small. The distribution of temperature deviations is indicated in Table 5. The grand average deviation for the 68 points is 1.5 deg. cent. (2.7 deg. fahr.).

Loss curves for fuels B4 and 704, together with the distillation curves, are shown graphically in Figs. 2 and 3 respectively. The lower curve in each figure is the temperature-loss curve, whereas the upper set of curves represent distillation data on the original fuel and on a number of the residues. To avoid confusion, distillation curves are not shown for all of the residues in each case. It is to be noted that the slope of the temperature-loss curve in the case of fuel 704 is much less than that for fuel B4. In general, it was found that the slope of the loss curves paralleled the slopes of the distillation curves. Thus, for a gasoline with a steep slope over the initial-distillation range, the change in the loss by weathering would be comparatively small for a fairly large change in the temperature of weathering.

These experiments over a range of temperatures indicate that the A.S.T.M. 10-per cent point of the residue after weathering may be evaluated with considerable accuracy from the measured loss and the distillation curve of the original fuel. Since, with most gasolines, the vapor-locking tendency is determined by the 10-per

TABLE 6—EFFECT OF PRESSURE ON WEATHERING LOSS

Fuel	Orifice Diam., In.	Time, Min.	Temperature Deg. Cent.	Temperature Deg. Fahr.	Pressure Mm. Hg.	Pressure In.	Loss, Per Cent	Superheat Deg. Cent.	Superheat Deg. Fahr.
104A	1/8	60	40	104	380	14.96	37.8	19	34
					570	22.44	10.7	7	13
					760	29.92	0.4	− 3	− 5
...	..	..	30	86	380	14.96	11.8	9	16
					570	22.44	0.2	− 3	− 5
...	..	..	20	68	380	14.96	0.6	− 1	− 2
					570	22.44	0.2	−13	−23
...	..	15	40	104	380	14.96	34.7	19	34
					570	22.44	5.0	7	13
...	1/32	15	40	104	380	14.96	28.3	19	34
					570	22.44	3.7	7	13
...	1/16	15	40	104	380	14.96	25.6	19	34
					570	22.44	4.1	7	13
...	1/32	15	40	104	380	14.96	13.6	19	34
					570	22.44	3.6	7	13
124A	1/8	15	50	122	380	14.96	2.8	5	9
					570	22.44	0.6	− 9	−16

cent point, a knowledge of the weathering loss permits an evaluation of the change in the vapor-locking tendency on weathering. In general, the loss is not known, but a method for obtaining this from the conditions of weathering will be discussed later in the paper.

In the evaluation of the 10-per cent point of the residue, the temperature on the original curve at a percentage evaporated equal to 10 plus the loss was used. A study of the distillation data for all of the fuels and residues in Table 4 indicated that the 50-per cent point of the residue could be obtained by reading the temperature on the original curve at a percentage evaporated equal to 50 plus one-half of the loss. The average deviation from this relation for the 68 cases was found to be 1.0 deg. cent. (1.8 deg. fahr.). Similarly, the 90-per cent point of the residue was observed to be equal to the temperature on the original curve at a percentage evaporated of 90 plus one-tenth of the loss. The average deviation in this case is 1.6 deg. cent. (2.9 deg. fahr.).

Effect of Pressure

The results obtained in studying the effect of pressure on the weathering loss are summarized in Table 6. For the same bath temperature, the amount of loss decreases rapidly with increase in external pressure. This presumably is due to difference in the extent of superheating, values for which are recorded in the last column. A more logical comparison can be made at degrees of superheat corresponding to the same pressure difference rather than at the same bath temperature. Such a comparison is made in Table 7. The losses given at 380 mm. (14.96 in.) were read from the temperature-loss curves at temperatures corresponding to the same pressure difference as for the 570-mm. (22.44 in.) ex-

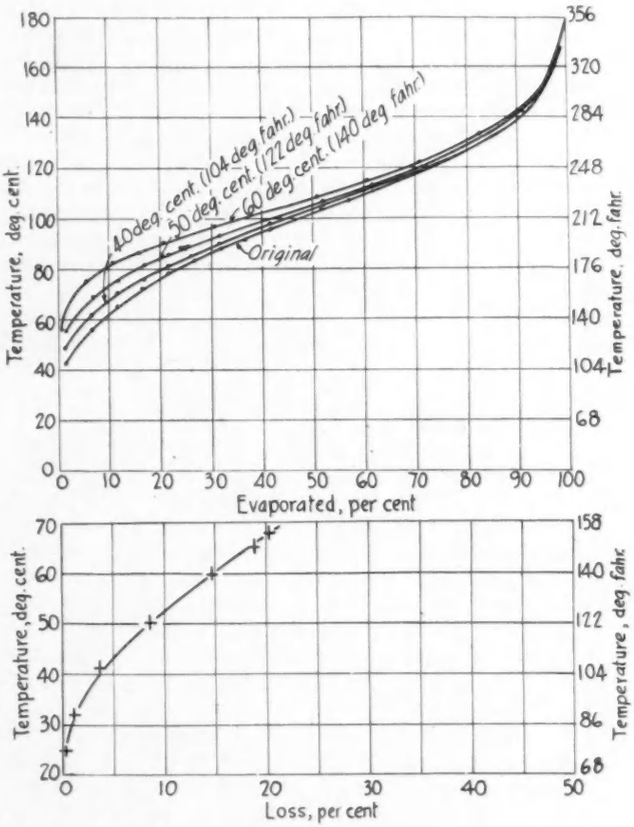


FIG. 2—TEMPERATURE-LOSS CURVE FOR FUEL B4, 1930 DOMESTIC AVIATION GASOLINE

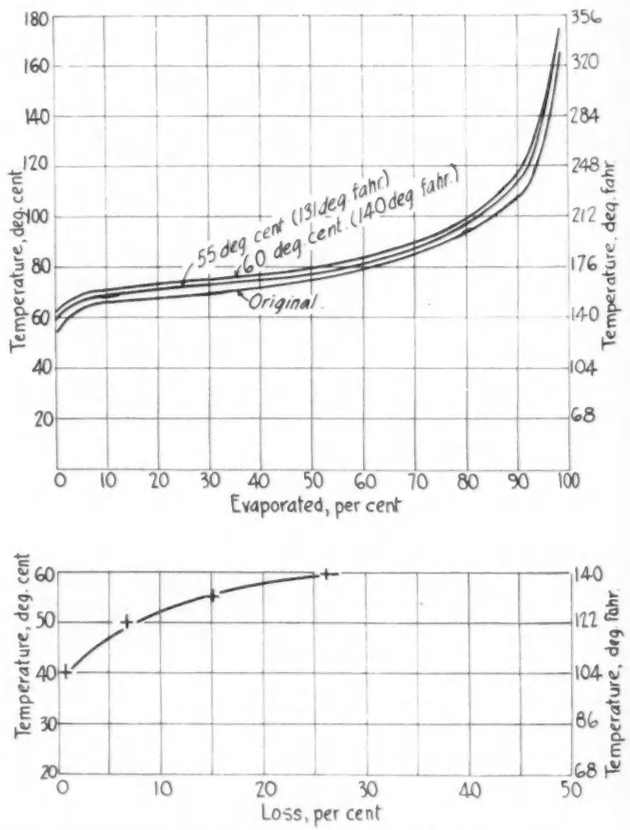


FIG. 3—TEMPERATURE-LOSS CURVE FOR FUEL 704, A BLEND OF 90 PER CENT NATURAL GASOLINE AVIATION FUEL AND 10 PER CENT GRADE-A NATURAL GASOLINE

The Lower Curve in Each Figure Is the Loss Due to Temperature Difference. The Curves in the Upper Set Represent Distillation Data on the Original Fuel and on Several Residues. Note That the Slope of the Temperature-Loss Curve in the Case of Fuel 704 Is Much Less than That for Fuel B4; also that the Slope of the Loss Curves Parallels That of the Distillation Curves

periments. The agreement is fair between the losses at the two pressures, for the same pressure difference. Hence, in the weathering of gasolines, it appears that the amount by which the vapor pressure exceeds the external is the controlling factor in the amount of loss, pressure, rather than the actual values of the temperature or pressure.

Time of Weathering

It was noted in Table 3 that the observed losses were usually lower than the computed maximum values, and this was attributed to the fact that sufficient time was not allowed for removal of all of the vapors. A number of experiments were made in which the loss was determined for different periods of heating. The data obtained are shown in Table 8 and are applicable to the following experimental conditions: Pressure, 380 mm. (14.96 in.); orifice 1/8 in. With the exception of the data on fuel 124A, the results indicate that, with sufficient time of weathering, the loss obtained will correspond closely with the computed maximum value.

This computed maximum value is based on the assumption that weathering will take place rapidly until the vapor pressure of the residual liquid drops to equality with the external pressure at the bath temperature. This involves the conclusion that, if a series of gasolines maintained at the same temperature are all in a superheated state, the magnitude of which may vary, weathering will occur until all have the same vapor pressure or, very closely, the same 10-per cent point.

In the section on the effect of temperature on weathering, it was reported that the 10-per cent point of the residual gasoline was equal to the temperature on the distillation curve of the original gasoline at a percentage evaporated equal to 10 plus the loss on weathering. Hence, making the assumption mentioned regarding the vapor pressure of the residue, the maximum loss can be obtained (*a*) by computing the 10-per cent temperature of a gasoline which would have the desired vapor pressure at the bath temperature; (*b*) by evaluating the percentage evaporated on the distillation curve of the original gasoline at the computed temperature, and, finally, (*c*) by subtracting 10 from the observed percentage evaporated. The experimental results in Table 8 furnish considerable evidence for the validity of this procedure. The lack of agreement in the case of fuel 124A is probably due to the fact that it is only slightly superheated and that the distillation curve is extremely flat, the change in temperature from the 10 to the 50-per cent point being only 7 deg. cent. (13 deg. fahr.). In this case, slight errors in the bath temperature or in the distillation are greatly magnified in computing the maximum loss.

The types of time-loss curves obtained in these experiments are illustrated in Fig. 4 for fuels 104A, C4 and 814.

TABLE 7—EFFECT OF PRESSURE AT CORRESPONDING DEGREES OF SUPERHEAT

Fuel	Orifice Diameter, In.	Time, Min.	Superheat, Deg. Cent.	Superheat, Deg. Fahr.	Pressure, Mm. Hg.	Pressure, In.	Loss, Per Cent	Difference, Per Cent
104A	1/8	60	9	16	380	14.96	11.8	
			7	13	570	22.44	10.7	−1.1
		15	9	16	380	14.96	8.1	
			7	13	570	22.44	6.5	−1.6
	5/32	15	9	16	380	14.96	6.0	
			7	13	570	22.44	3.7	−2.3
	1/16	15	9	16	380	14.96	5.4	
			7	13	570	22.44	4.1	−1.3
	1/32	15	9	16.2	380	14.96	4.3	
			7	13	570	22.44	3.6	−0.7

TABLE 8—EFFECT OF TIME OF WEATHERING ON LOSS

Fuel	Temperature, Deg. Cent.	Temperature, Deg. Fahr.	Time, Min.	Observed Loss, Per Cent	Computed Maximum Loss, Per Cent
104A	40	104	5	16.2	41
			10	29.7	
			15	34.7	
			30	37.1	
			60	37.8	
124A	50	122	5	1.6	35
			10	1.9	
			15	2.8	
			30	3.0	
154	60	140	10	18.1	24
			15	18.9	
			30	21.5	
			60	22.6	
84	78	172	15	15.3	19
			25	18.8	
			35	19.0	
...	70	158	15	10.6	13
			25	13.2	
			35	13.8	
B4	70	158	60	27.7	28
			90	30.0	
			110	31.5	
			130	32.8	
C4	70	158	15	12.1	20
			25	19.0	
			35	19.9	
			45	20.6	
814	60	140	15	15.0	70
			30	25.2	
			60	32.5	
			90	36.1	
			125	44.3	
			155	49.2	

Effect of Orifice Size

The effect of the size of orifice used on the tank during weathering is analogous to the effect of time. Increasing the orifice size permits removal of a greater

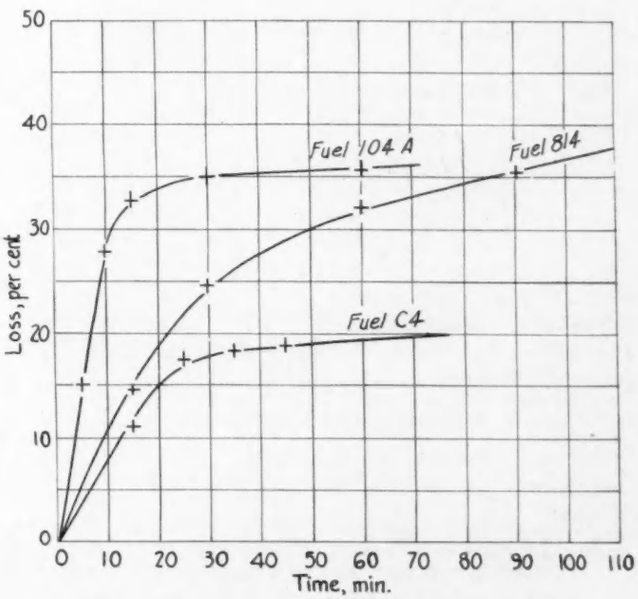


FIG. 4—TIME-LOSS CURVES FOR THREE FUELS

These Show the Percentage Losses Due to Weathering over Varying Times of Heating

volume of vapor per unit time and hence decreases the time necessary for the practical completion of weathering. The results obtained when using the different orifices are shown in Table 9. In those cases where the loss is small, the smallest orifice appears adequate to remove all of the vapor; where the loss is large, the change in the values with decrease in the orifice size is dependent upon the time of weathering, as illustrated by fuel 104A at 40 deg. cent. (104 deg. fahr.) with 15 and 60-min. heating. The abrupt change in the case of fuel 184 at 70 deg. cent. (158 deg. fahr.) between the 1/16 and 1/32-in. orifices is interesting.

TABLE 9—EFFECT OF ORIFICE SIZE ON WEATHERING LOSS

Fuel	Pressure Mm. Hg.	Pressure In.	Temperature Deg. Cent.	Temperature Deg. Fahr.	Time, Min.	Orifice Diameter, In.	Loss, Per Cent
104A	380	14.96	40	104	15	1/8	34.7
						1/16	25.6
						1/32	13.6
...	...	.....	..	...	60	1/8	37.8
						3/32	34.0
						1/16	31.2
						1/32	29.4
..	....	.....	30	86	60	1/8	11.8
						3/32	12.0
						1/16	9.9
						1/32	10.7
...	570	22.44	40	104	15	1/8	5.0
						3/32	3.7
						1/16	3.8
						1/32	3.6
124A	380	14.96	50	122	5	1/8	1.6
						3/32	1.2
						1/16	1.4
						1/32	1.4
184	380	14.96	70	158	15	1/8	23.6
						3/32	23.8
						1/16	22.9
						1/32	14.7
...	...	.....	60	140	15	1/8	15.8
						3/32	14.8
						1/32	9.8
...	...	.....	50	122	15	1/8	4.9
						3/32	3.9
						1/16	4.4
						1/32	2.8
...	...	.....	..	...	30	1/8	5.0
						3/32	5.1
						1/16	4.7
						1/32	2.1

The effect of orifice size is illustrated graphically in Fig. 5 for fuel 184 at 70, 60 and 50 deg. cent. (158, 140 and 122 deg. fahr.).

Summary and Conclusions

The general conclusions which can be drawn from the experiments on weathering may be summarized as follows:

(1) The amount of loss which occurs on weathering for a given gasoline for a given period of time in a specific apparatus is dependent primarily upon the maximum pressure-difference and is dependent only indirectly upon the actual values of the temperature and external pressure. The maximum pressure-difference is the amount by which the vapor pressure of the original gasoline can exceed the external pressure, at any given temperature.

(2) If there is no pressure difference, very little loss occurs during the period of time occupied by a usual airplane flight.

(3) If there is a pressure difference, the amount of loss depends upon the magnitude of this difference and may depend upon the length of time during which superheating occurs and upon the size of opening from the tank.

(4) For a given pressure-difference and a given size of opening, the loss increases with time of superheating up to a definite value for each gasoline and then changes very slowly with additional time.

(5) For a given pressure-difference and a given time of superheating, the loss increases with increase in size of opening from the tank up to a definite value determined by the conditions.

(6) When loss occurs, the A.S.T.M. temperature of the residual gasoline at 10 per cent evaporated is equal to the temperature on the distillation curve of the original gasoline at a percentage evaporated equal to 10 plus the loss on weathering.

(7) When a gasoline is superheated at a given temperature and pressure, loss occurs until the vapor pressure of the residue, at the temperature under consideration, is reduced to the given external pressure. Thus, if a series of gasolines are all in a superheated state at this pressure and temperature, loss will occur until the 10-per cent points of the residues are approximately the same.

This work leads to a definite rule for evaluating the maximum amount of loss from a tank three-quarters full of liquid when superheated over a sufficient period of time at a given temperature and pressure, which may be expressed as follows:

Substitute the temperature of weathering and the external pressure in the general vapor-pressure relation and compute the A.S.T.M. 10-per cent point which satisfies these conditions. Read the percentage evaporated corresponding to this computed temperature on the A.S.T.M. distillation curve of the fuel. Subtracting 10 from this percentage evaporated gives the computed maximum loss under the conditions. The actual loss may be less than this value if the time of superheating is very short or the size of opening from the tank is very small.

In applying the general conclusions to the problem of vapor lock, the following statements seem justified:

(*a*) Any change in the vapor-locking tendency of a gasoline will be very small until the gasoline is superheated.

(*b*) If a series of gasolines are all maintained in the superheated state for a sufficient period of time, they will ultimately have the same vapor-locking tendency, which depends upon the chosen temperature and pressure. However, the actual amounts of loss in the case of the various gasolines may be quite different.

(*c*) Vapor lock may be expected to occur before the gasoline has weathered sufficiently in the tank to change its vapor-locking tendency. This will be particularly true with airplane fuel-systems employing a fuel pump.

(*d*) If vapor lock does not occur before the gasoline tends to become superheated, it is probable that weathering will automatically prevent its occurrence.

(*e*) The temperature at which a gasoline begins to superheat at 380 mm. (14.96 in.) or at 18,000-ft. altitude is aproximately 25 deg. cent. (45 deg. fahr.) below the 10-per cent point. Hence, except with very volatile fuels or unusually high temperatures in the tank, it would not be expected that much loss by weathering would occur in most cases. An altitude of 18,000 ft. is about the highest which would require consideration, for, above that altitude, supercharging would normally be used.

The work outlined was largely concerned with aviation fuels and the atmospheric conditions encountered during flight. However, the conclusions are also applicable to motor fuels. In this case the pressure is usually about 760 mm. (29.92 in.) and the gasoline would have to be heated to the 10-per cent point before much loss would occur in the main tank, with the exception of propane blends, which might show considerable loss below the 10-per-cent-point temperature. In the vacuum tank, the pressure would be lower than 760 mm. (29.92 in.) and hence lower temperatures would be required to reach the superheated state. In the case of automobile fuel-systems, little loss by weathering would be expected over short periods of time unless the temperatures were abnormally high or an unstabilized fuel was used.

This investigation was undertaken as part of a fundamental study of vapor lock in automotive fuel-systems.

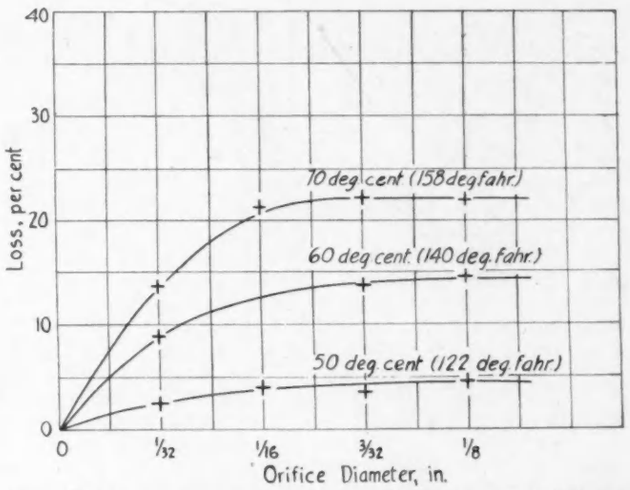


FIG. 5—VARIATION IN PERCENTAGE OF LOSS WITH DIFFERENCE IN SIZE OF ORIFICE

Increase in Size of Orifice Permits More Rapid Removal of Vapor and Decreases the Time Necessary for Virtually Complete Weathering

Its inauguration, limited to airplane systems, was made possible by a contribution from the Naturaline Co. of America and was at first conducted under the direction of the Research Committee of the Society of Automotive Engineers. In September, 1929, the supervision of this investigation was accepted by the Cooperative Fuel Research Steering Committee and its scope was extended to include automobile fuel-systems.

Small Diesel Engines

(*Concluded from p.* 284)

made to work in unison by short levers on a shaft which is actuated by the engine governor or the hand throttle and causes the metering pins to take a position which will permit the passage of the amount of fuel necessary to carry the engine load, increasing or decreasing the effective area of the metering orifice and seating only momentarily when all the load is suddenly taken from the engine.

A speed varying not more than 3 per cent from no load to rated load is maintained by this governing device. Engines equipped with this fuel system operate efficiently on fuels from 20 to 40 deg. Baumé with virtually no smoke. Fuels below 24 deg. Baumé must be warmed to make them flow through the pumps, and it is best not to let the engine cool with such fuels in the system. The fuel consumption in the 5 x 7-in. and 6 x 10-in. models is from 0.42 to 0.46 lb. per hp-hr., according to the heating value of the fuel.

Avoiding fine orifices liable to stoppage and keeping the number of delicate parts at the minimum were the chief objectives in developing this system.

Fig. 7 illustrates a 3½ x 6-in. light-weight engine for automotive service, with transmission. The general design follows automotive practice closely. The cylinder-block and cylinder-head are cast from chrome nickel iron. The base, oil-pan, manifolds, housings and covers are of heat-treated aluminum alloy. The pistons are cast from special low-expansion aluminum alloy. The spiral-cut gears are of hardened steel. The pump shafts are of Nitralloy steel running in Timken roller-bearings. The flywheel housing is S.A.E. No. 2 size. An end section is given in Fig. 8.

Other Hill engines are made having 6 x 10-in. and 5 x 7-in. cylinders. The six-cylinder marine-propulsion engine of the larger of these sizes is rated at 120 hp. at 800 r.p.m. The 5 x 7-in. six-cylinder marine-propulsion engine, shown on the first page of this paper, is rated at 75 hp. at 1000 r.p.m. Both cylinder sizes are built also for stationary service and in models having a smaller number of cylinders. Fig. 9 shows a combination auxiliary set, built around a single-cylinder 5 x 7-in. engine, for use on a ship.

Vapor-Locking Tendencies of Automotive Fuel-Systems

Discussion of W. C. Bauer's Semi-Annual Meeting Paper[1]

IN THE DISCUSSION, tests made to ascertain the tendency of different fuels to vapor lock are said to agree in all important details with those made to determine the effect of fuel systems, as reported by the author of the paper. They indicate a relationship between the vapor pressure and the temperature below which the fuel will not cause trouble due to vapor lock but also indicate that the temperature at which vaporization begins in the A.S.T.M. distillation is a more accurate index of the temperature at which definite vapor lock is observed.

Various possible means applicable to the car for preventing vapor-locking are discussed; among them, turning the carbureter intake around so that cooler air enters, placing the fuel lines so that they will not be exposed to heat from the exhaust pipe, removing the carbureter and gasoline filter farther from the exhaust manifold, dispensing with the vacuum tank and placing a fuel pump in the gasoline tank, placing an asbestos plate between the carbureter and the inlet-manifold riser, lagging the fuel lines, deflecting heat from the exaust pipe away from the carbureter and fuel pump and providing a supply of high-test fuel and a device to deliver a small quantity to the engine for starting in cold weather.

The difficulty is said to be that the operating range of temperatures between which the engine can be started easily and vapor-lock trouble occurs is about 140 deg. fahr., and the problem is to produce a fuel that will start an engine at a below-zero temperature and not cause vapor lock when the engine and fuel system reach a temperature 140 deg. higher.

CHAIRMAN B. B. BACHMAN[2]:—I believe I am correct in saying that originally the subject of vapor lock was believed to be of major importance in aviation and of relatively minor importance on the ground. Since research on the subject was started, we have almost come to an about-face in that attitude. Some excellent work has been done, and it gives us all valuable information, whether we are on the ground or in the air.

W. C. BAUER:—When an engine having an air-valve carbureter stalls as a result of vapor bubbles rising through the tube having an outlet but slightly above the fuel level and causing too rich a mixture, the engine is much harder to start again than is an engine fitted with a plain-tube carbureter. When the latter stalls, the mere opening of the throttle a little more seems to draw fuel from the main jet and gives a fairly easy start. Starting after a stall is usually very difficult when the bottom of the carbureter is loaded with fuel. It usually is overcome by opening the throttle wide.

W. C. BAUER

Referring to the curves of Fig. 1 in the paper, which is a record of exhaust analysis under constant-throttle constant-load operation, it will be noticed that the car speed remains fairly constant up to the region of vapor lock, when it begins to drop. The loss is quite apparent. There is a quick recovery to normalcy on cooling. The change in percentage of carbon monoxide in the exhaust is definite proof that in this case vapor lock is caused by a reduction of fuel flow.

GEORGE GRANGER BROWN[3]:—Mr. Bauer's paper is of particular value in placing the responsibility for vapor lock on the design of the fuel systems now in common use. His studies with 21 different cars clearly indicate the great differences in the tendency of different fuel systems to vapor lock.

Our work for the Natural Gasoline Association of America was concerned almost entirely with the tendency of different fuels to vapor lock, as distinct from the tendencies of different fuel systems to cause vapor lock. In all important details, our results are in entire agreement with those reported by Mr. Bauer.

The results reported in Bulletin No. 14 of the Engineering Research Department of the University of Michigan indicate a satisfactory but conservative relationship between the vapor pressure as determined in the Reid bomb and the temperature below which the fuel will not cause trouble due to vapor lock. Careful comparison also indicates that the temperature of the liquid in the distillation flask when vaporization begins in the course of the A.S.T.M. distillation is, on the average, a more accurate indication of the temperature at which definite vapor lock is observed. But in a few cases vapor lock was experienced at temperatures below that of the initial boiling-point of the liquid, when

[1] The paper was published in the S.A.E. JOURNAL, June, 1930, p. 736. The author is connected with the fuel and lubrication laboratories of the Standard Oil Development Co., Elizabeth, N. J. The abstract of the paper is not reprinted but a summary of the main points in the discussion precedes the discussion printed herewith.

[2] M.S.A.E.—Vice-president of engineering, Autocar Co., Ardmore, Pa.

[3] M.S.A.E.—Professor of chemical engineering, consulting engineer, University of Michigan, Ann Arbor, Mich.

this temperature was corrected for distillation loss.

A. L. CLAYDEN[4]:—I made a very small investigation into this subject somewhat along the lines that Mr. Bauer did, observing three different cars only, and was led to believe that the temperature of the carbureter was mainly controlled by the temperature of the air going into it. In one case simply turning the carbureter around resulted in an immediate drop of 40 deg. fahr. on a normal summer day. If the position of the air intake to the carbureter is the most important single factor, I think that should be brought out.

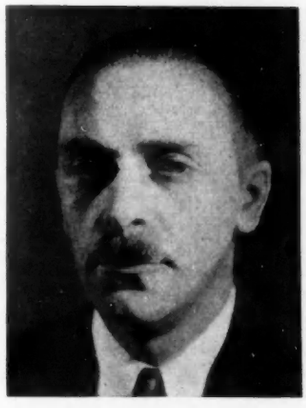
MR. BAUER:—It just caused the high fuel-temperatures of the various carbureters. We have run our vapor-lock determinations on the cars as we received them from the factory and have never tried the effect of different air horns and so forth, except that we have tried taking off air heaters and giving the particular car all the chance we could, such as the owner might give, to prevent vapor lock.

DR. O. C. BRIDGEMAN[5]:—How far do you think it would be possible to go in reducing the fuel-line temperatures in automobiles by redesign?

MR. BAUER:—If all cars were designed to operate with the same fuel-temperature as the best of the ones we have tested, there is no reason why a fuel having its 10-per cent point around 130 deg. fahr. should not function perfectly.

Should Keep Fuel Lines Away from Heat

A. L. BEALL[6]:—Will you explain the liquid initial boiling-point? From the fact that the temperature of the air under the hood is not given in Table 2, I assume that you found that the variations in the under-hood temperature might be rather wide without substantially affecting the fuel temperature. That has been our experience in some similar work.



A. L. BEALL

If it is generally true that the under-hood temperatures have not a great effect on the fuel temperature, it does not seem profitable to lag the fuel lines to keep the fuel cooler. The cure would seem to be to carry the fuel lines in some place where they are not exposed to particularly hot temperatures, as they are when near the exhaust pipe.

The weathering action in the heated vacuum tanks might be expected, but even though Dr. Bridgeman and Miss Aldrich show[7] that a great deal of loss through such weathering does not occur, the avoidance of vapor lock by such a superheat would hardly be conducive to economy. There seems to be little doubt as to the accuracy of Mr. Bauer's claim that vapor lock is more a factor of fuel-system design than of fuel. With reasonable precautions to remove propane from his supplies, the refiner has a very small choice of 10-per cent points to get suitable starting and avoid vapor locking in many modern cars.

J. P. STEWART

MR. BAUER: — I am sorry I cannot explain how this 10-per cent point is derived. I am not a chemist and am not fully familiar with laboratory inspection methods.

MR. BEALL: — Would you suppose that the 10-per cent point would be the liquid initial boiling-point or a point on the curve with the distillation loss subtracted?

MR. BAUER:—As I get the picture, the initial boiling-point is obtained by placing the bulb of the thermometer in the flask and taking the temperature when the first drop forms in the condenser.

Experimenting with Pump in Fuel Tank

J. P. STEWART[8]:—I have received the impression from Mr. Bauer's paper that complete stoppage of the vehicle is due to vapor locking in the line leading to the carbureter rather than in the carbureter, and that lack of power without stoppage is due, in the main, to vapor formation actually in the jets or in the carbureter parts.

Is not the filter the most prone to give vapor locking in the lines to the carbureter? In many of the cars the filter sets down close to the exhaust manifold. I have seen filters that were only 1½ or 2 in. away from it. When vapor locking occurs on the road, bubbles can be seen in the glass bowl of the carbureter.

One rather well-known car has been giving trouble with vapor-locking. I believe that the manufacturers are experimenting with dispensing with the vacuum tank, placing the fuel pump in the gasoline tank at the rear of the car and pumping from there to the carbureter by means of an electrically operated pump. They have carried on experiments in the mountains of Pennsylvania under conditions where the car originally vapor locked. With the new pump-arrangement, we experienced no difficulties from this source with the experimental car. The trouble in the mountains was caused evidently by locking in the lines and the carbureter, because complete stoppage of the engine occurred.

DR. BRIDGEMAN:—I cannot agree entirely with Mr. Bauer's conclusion that trouble from vapor locking is more a factor of design rather than of fuel. That probably is true with a considerable number of the fuels sold throughout the Country, but if at the limit of cooling the temperature of the fuel system is still 25 deg. fahr. or thereabouts above the atmospheric temperature, certainly fuels which the refiner can and very frequently does produce would give trouble. I know of fuels distributed throughout the Country which run as low as 100 deg. fahr. at the 10-per cent point in the summer. With such a fuel, I would say that the trouble is due entirely to the fuel. It is unfortunate, from certain viewpoints, that more casinghead gasoline cannot

[4] M.S.A.E.—Research engineer, Sun Oil Co., Norwood, Pa.

[5] S.M.S.A.E.—Research associate, Bureau of Standards, City of Washington.

[6] M.S.A.E.—Engineer, Vacuum Oil Co., Ridgefield, N. J.

[7] See paper on The Effect of Weathering on the Vapor-Locking Tendency of Gasolines, S.A.E. JOURNAL, September, 1930, p. ???

[8] M.S.A.E.—Automotive research engineer, Vacuum Oil Co., Paulsboro, N. J.

be used in the fuel; but I think it is a fact that the fuel-feed system does limit the volatility of the fuels that can be used, so the problem involves both industries and its solution represents a compromise between the two.

MR. BAUER:—I do not want to argue the point with Dr. Bridgeman. My paper was intended as a plea for the automobile manufacturers to establish somewhere near a standardized temperature so that the refiners can make a suitable fuel.

MR. BEALL:—I should like to take issue with Dr. Bridgeman. It is true that many gasolines have much too low a 10-per cent point. However, in the winter in the northern temperate climate some cars will virtually reproduce the temperatures Mr. Bauer shows in operation, and they must start readily. What can the refiner do? He has to have a gasoline that will start the car before he can sell the gasoline. If it will not start the engine it is not much good. After the fuel has started the engine at atmospheric temperature, the driver may expect to encounter vapor lock, not every day but on many days throughout the winter months.

Wants Remedy Applicable to Old Cars

ROBERT E. WILKIN[9]:—We all know that most of the automobile manufacturers are attempting to correct conditions that are causing vapor lock; however, we still have to service cars that were made five, six and seven years ago, some of which may be over-hot-spotted or possess other factors that cause serious vapor lock. I should like to hear some suggestions as to what simple remedy might be applied to such a car to prevent vapor lock. If the trouble is caused by vapor locking in the carbureter, particularly during idling following fast driving, we might secure advantage by placing a fairly thick asbestos gasket between the carbureter and the riser. I believe that a large percentage of the heat flows from the hot-spot and the exhaust manifold through that joint to the carbureter under idling conditions. I have suggested such procedure to some customers but so far have not had a report as to the results. Has anyone had any experience in controlling vapor lock in this way? Also, there is a question whether lagging the fuel lines may be of some value.

O. C. BRIDGEMAN

MR. BEALL:—I know that Mr. Wilkin's suggestion has been effective on two or three models.

MR. BAUER:—On one particular car, with the vacuum tank placed as the car came from the factory, we found that vapor locking was virtually impossible. However, the car could be made to perform all kinds of vapor-locking stunts by shifting the vacuum tank. On a warm day, if this car was driven until the vacuum tank was dry and then refilled with cold gasoline, operation of the engine was impossible until the fresh fuel had had some chance to weather off the light ends.

MR. STEWART:—I should like to add one thought to show a somewhat complicated condition. The refiners are endeavoring to supply a fuel that will give satisfactory service from the vapor-lock standpoint. The tendency today is to provide a more volatile fuel in the winter than in the summer. When spring comes, sometimes early, probably more vapor-lock trouble is experienced than even in the summer, because the more volatile gasolines are still being supplied for the winter season. A hot day comes and severe vapor locking occurs. Anything that can be done to simplify or improve the fuel systems to guard against this is a double gain.

Separate Supply of Starting Fuel

F. W. HECKERT[10]:—A possible solution for motor-vehicles might be to have two sources of fuel on the vehicle, one for high-test gasoline, with some device capable of delivering that volatile fraction or percentage to the carbureter for starting under cold-weather conditions. For instance, starting aircraft engines in the northern regions in winter is a very serious problem. During the maneuvers of the Army pursuit group in the Northwest last winter we installed a Lunkenheimer pump having a two-way or three-way inlet valve. One inlet line from the control valve ran down into a can or jar of ether that the pilots carried, and the other suction line was connected to the fuel-supply system. By turning the valve to a position marked "Ether" and giving the engine a shot of ether, the pilot could start without difficulty. Some arrangement of this character, in my opinion, might help, thereby enabling the refiner to produce a more uniform fuel and eliminate the high-test fractions that tend to vapor locking.

DR. BRIDGEMAN:—Mr. Heckert brought out a rather important point; that is, the problem of starting the engine easily. There is, roughly, an operating range of 140 deg. fahr. between the temperature at which the engine can be started easily and the temperature at which trouble arises from vapor lock. A gasoline that will just start the engine easily at 0 deg. fahr. will give trouble from vapor lock at approximately 140 deg. fahr. With cars equipped with thermostatic shutters, the temperatures in the winter are not very much lower than they are in the summertime, which means that, if it is necessary to start at 20 deg. below zero and one is still to avoid vapor lock, he is confronted with a very perplexing problem. If the refiner produces a fuel that will start the engine at 20 deg. below zero, the chances are that the car will have vapor-lock troubles in the winter. A possible solution for that is the sort of arrangement that Mr. Heckert suggests; namely, an auxiliary starting-fuel. It would be complicated and might be objectionable from certain viewpoints, being another accessory on the car; but it is a solution for starting at very low temperatures unless some other means can be used to cool the fuel system.

MR. BEALL:—In Austria the range of fuels for winter service will have 10-per cent points between something like 160 and 175 deg. fahr. They never have a complaint about starting there. That range represents the products of all the Austrian manufacturers. Every car is equipped with some kind of device, if it is only a plug, through which the engine can be primed. I think

(*Concluded on p. 359*)

[9] M.S.A.E.—Automotive engineer, Standard Oil Co. of Indiana, Chicago.

[10] M.S.A.E.—Associate mechanical engineer, powerplant branch, Materiel Division, Air Corps, Wright Field, Dayton, Ohio.

Preliminary Study of Riding-Qualities

By Dr. G. C. Brandenburg[1] and Ammon Swope[2]

THE PRELIMINARY study herein reported in a paper that was presented at the Semi-Annual Meeting in May, 1930, was entered upon under the direction of Dr. G. C. Brandenburg, who is a member of the Purdue University committee named in 1928 by Prof. H. M. Jacklin, of the faculty of the University, to undertake the experimental study of this subject in the Department of Psychology.

The suggestion for the study was made by Edward P. Warner, a member of the S.A.E. Riding-Qualities Subcommittee, at a meeting of the Subcommittee held Nov. 16, 1928, at the Bureau of Standards in the City of Washington, in the following words: "(1) Correlation of 'feelings' of subjects, with some statistical expression to get numerical measurement of fatigue produced."

The purpose of the study reported herein was to investigate the subject of feelings involved in the riding-qualities of an automobile. It is believed that these feelings have much to do with the apparent comfortable qualities of the machine. Incidental to this objective was the effort to discover contributory conditions that might influence or be interpreted as riding-qualities. A further purpose was to devise a more accurate scale for measuring those qualities. This last purpose is yet to be realized.

Method of Investigation

As the study proposed to investigate feelings, the first attempt at formulating a method of attack was by engaging ten different persons in conversation on what seemed to them to be desirable and undesirable conditions in the riding-qualities of an automobile. Some of the responses were very positive, showing strong likes and dislikes on the part of a few. All responses were tabulated and analyzed. They furnished the basic ideas of grading responses to a series of questions.

The classification of the 24 items in the scale used shows the following groups of sensory qualities:

(1) Motion.
(2) Sound.
(3) Sight.
(4) Smell.
(5) Spatial Relations.
(6) Esthetics.

The form of the scale is modeled after the Purdue Rating Scale. This form was adopted because of its reliability and ease of administering. The title for each item in the scale is written in language that is commonly used and understood. This statement was found by explaining the idea to someone not interested directly in the study and having him put it into his own words. The explanatory notes were decided on in the same way. These, however, were varied from item to item to preclude a set response for a succession of items.

The ratings of 125 persons, 79 men and 46 women, were taken. About two-thirds of this group was composed of university students. The accompanying tables indicate the accumulated attitudes and give personal data of those who marked the scale.

Evaluation of the Data

The results of the study are displayed in two ways: First, the well-known methods of statistical evaluation have been used. The arithmetic mean and the standard deviation are given for each of the 24 items for the total number of cases. The probable error of the mean is given also. This method of evaluation is repeated for each of the sexes. In addition, the probable error of the difference of the means between the sexes has been computed (See Table 1). Second, graphical displays are given to aid in clarifying the data of the tables. The positions of the mean and of plus and minus the standard deviation have been located. The degree of feeling on any item is represented by the abscissa of that point and corresponds to the position on the scale

[1] Professor of education and psychology, Purdue University, Lafayette, Ind.

[2] Associate professor of industrial education, Purdue University, Lafayette, Ind.

TABLE 1—STATISTICAL DATA FROM REPLIES TO QUERIES ON SENSORY FEELINGS WHEN RIDING

Item	MEN AND WOMEN			MEN			WOMEN			Mean Difference	±P.E. Difference
	Mean[3]	±P.E.m.[4]	±S.D.[5]	Mean[3]	±P.E.m[4]	±S.D.[5]	Mean[3]	±P.E.m[4]	±S.D.[5]		
1. Vertical Motion	25.16	1.14	18.99	27.94	1.80	19.03	24.78	1.91	19.28	2.16	2.6
2. Swaying Motion	36.52	1.01	16.89	42.25	1.75	16.34	30.65	1.70	17.02	11.60	2.43
3. Skidding	35.64	1.48	24.79	40.49	1.62	17.07	29.13	1.93	19.30	20.89	2.49
4. Speed You Enjoy Most on Open Road	61.32	0.70	11.70	64.80	1.14	12.76	58.91	1.07	10.73	5.89	1.30
5. Acceleration You Prefer	70.44	1.26	21.14	78.53	1.78	18.77	58.70	1.90	19.04	19.83	2.60
6. Retardation	56.36	0.94	15.70	61.27	1.58	16.68	51.74	1.56	15.61	9.53	2.17
7. Roar from Car	39.48	1.59	26.51	45.20	1.77	28.18	38.04	2.60	26.03	6.16	3.14
8. Body Squeaks	16.44	0.90	14.99	14.22	1.23	12.96	20.22	1.66	16.65	6.00	2.06
9. Noise from Engine	29.00	1.14	18.97	30.29	2.01	21.26	28.91	1.89	18.94	11.38	2.75
10. Noise from Brakes	34.99	1.14	19.09	36.18	1.76	18.54	35.22	1.95	19.50	0.96	2.60
11. Noise from Tires	49.40	1.04	17.42	61.86	1.80	19.04	51.09	1.53	15.39	10.77	2.30
12. Noise from Wind	43.40	1.27	21.22	51.06	1.72	18.37	47.39	2.08	20.88	3.67	2.69
13. Unidentified Noises	19.65	0.90	15.08	19.70	1.48	15.63	23.91	1.50	15.07	4.21	2.10
14. Desirable Amount of Visibility	82.60	0.90	15.15	84.41	1.29	13.64	76.52	1.83	18.38	7.89	2.23
15. Odors from Engine	25.72	1.03	17.20	25.20	1.75	18.52	21.52	1.54	15.49	53.68	2.33
16. Most Desirable Position in Seat	51.80	1.20	20.10	53.24	1.76	16.53	53.04	2.12	21.22	0.20	2.75
17. Resiliency of Seat	63.72	1.45	24.23	65.98	1.60	16.94	62.39	1.35	13.58	3.59	2.09
18. Kind of Upholstery	67.64	1.24	20.80	61.08	2.41	25.44	70.87	1.60	16.09	8.79	2.89
19. Arm Rests	50.90	1.53	25.60	55.20	1.64	27.78	53.70	2.71	27.18	1.50	3.17
20. Foot Rests	64.36	1.43	23.90	62.25	2.43	25.67	66.30	2.24	22.42	4.05	3.30
21. Depth of Seat from Front to Back	60.10	1.20	20.10	67.75	2.04	21.51	55.00	1.92	19.22	12.75	1.67
22. Height of Front of Seat from Floor	33.64	0.86	14.44	31.08	1.57	16.57	35.65	1.22	12.33	4.57	2.22
23. Body Room	73.32	0.96	16.09	76.18	1.50	15.79	70.00	1.57	15.71	6.18	2.17
24. Interior Decorations	54.76	1.27	21.20	54.02	1.96	20.70	57.61	2.15	21.52	3.59	2.91

[3] Arithmetic Mean. [4] Possible Error of Difference of Means. [5] Standard Deviation.

which the rater has marked. The ordinate position indicates the number of persons who rated at any given point. The titles of the graphs correspond to the items on the scale.

The graphical comparison of the sexes is only approximately correct, since the number of cases differs, there being in these groups 51 men and 46 women. These groups are comparable in age, all being under 30.

Interpretation of the Data

(1) *Vertical Motion.*—The positions of the A.M. (arithmetic mean) and S.D. (standard deviation) in Fig. 1 indicate a feeling of annoyance on the part of the majority of the subjects, although there is a wide variation. The modal value indicates that about one-third of the group regard vertical motion as very annoying. There is no significant sex difference, as is shown by the P.E.m—m. (probable error of difference of means) in Table 1.

(2) *Swaying Motion.*—This motion is objectionable, but not as much so as the vertical motion. It is evident from Fig. 2 that the swaying motion is nauseating to many and extremely so to a few. The modal value in this item falls above the arithmetic mean. The sex difference here is significant, motion being more objectionable to women.

(3) *Skidding.*—While the arithmetic mean would indicate some anxiety on the part of all the subjects, the standard deviation shows a wide variation. Here again there is a significant sex difference, the motion being more objectionable to women.

(4) *Speed Enjoyed Most on Open Road.*—The limits of speed are from 10 to 80 m.p.h. on a scale of zero to 100. This gives an arithmetic mean of 42 m.p.h. The modal value is 45 m.p.h. There is no significant sex difference.

(5) *Acceleration.*—This is clearly a bimodal distribution. Comparing the two graphs in Figs. 4 and 5, it will be seen at once that the difference is due to sex. However, there seems to be a group that prefers extremely quick pick-up as distinguished from normal acceleration.

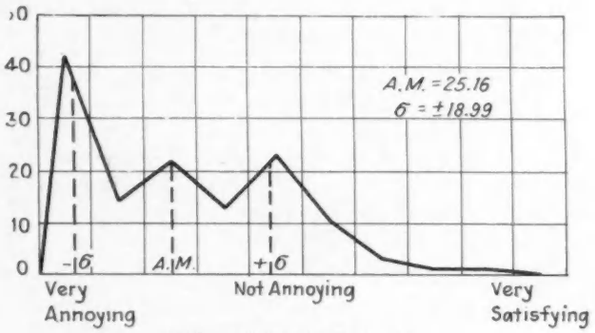


FIG. 1-VERTICAL MOTION

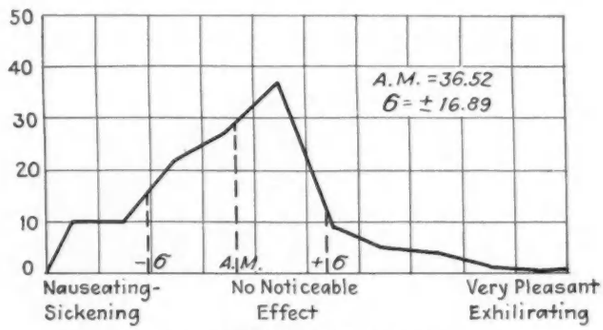


FIG. 2-SWAYING MOTION

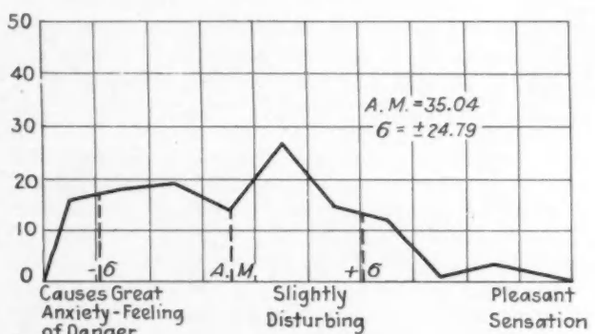


FIG. 3-SKIDDING

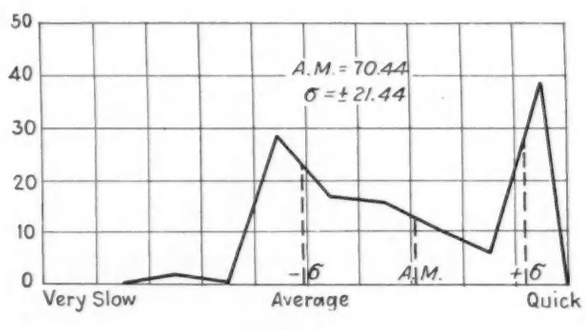


FIG. 4-ACCELERATION YOU PREFER

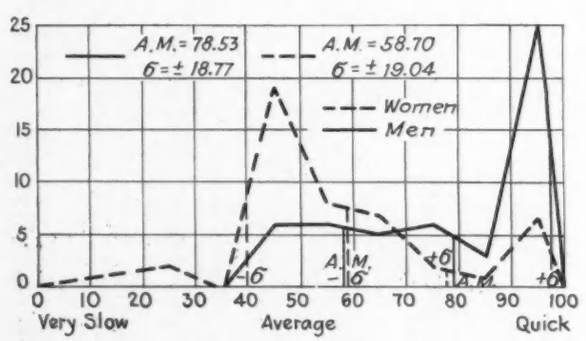


FIG. 5-ACCELERATION YOU PREFER

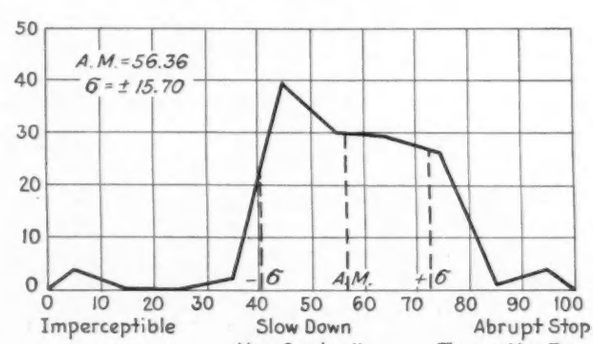


FIG. 6-RETARDATION

(6) *Retardation.*—More uniformity of agreement is found in deceleration than in acceleration, the difference of the means between the sexes being in acceleration 19.83, while in deceleration the difference is 9.53 (See Table 1 and Fig. 6). Both differences, however, are significant.

(7) *Roar from Car.*—The range of effect here is very great, there being an appreciable group who find the roar from a closed body very annoying. The arithmetic mean, however, shows that this roar is only slightly disturbing on the average (See Table 1).

(8) *Body Squeaks.*—The unimodal curve, the position and small probable error of the arithmetic mean and the small variation in the standard deviation in Fig. 7 all indicate the significance of the study with reference to body squeaks. Noises arising from these sources are highly distracting.

(9) *Noise from Engine.*—This seems in the main to cause some concern. It at least never creates a pleasant feeling. There are no significant sex differences.

(10) *Noise from Brakes.*—The curve in Fig. 8 is bimodal. This may be due to the fact that in some cases the noise is annoying but does not create a feeling of danger. Complete elimination of noise from brakes is desirable.

(11) *Noise from Tires.*—The noise from tires is noticeable and creates a small measure of satisfaction. The sex difference shown in Table 1 is significant, the

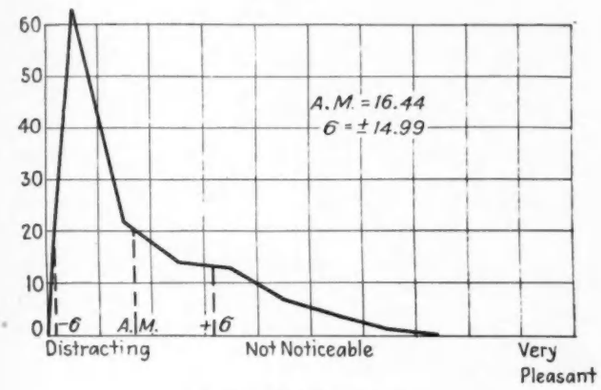


FIG. 7 - BODY SQUEAKS

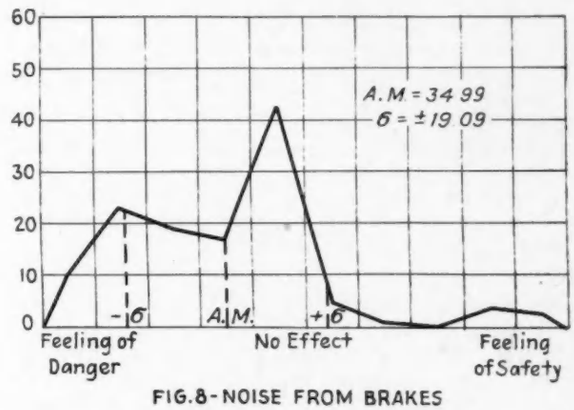


FIG. 8 - NOISE FROM BRAKES

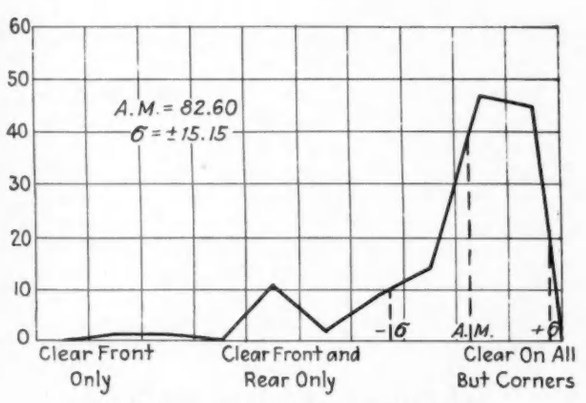


FIG. 9 - DESIRABLE AMOUNT OF VISION

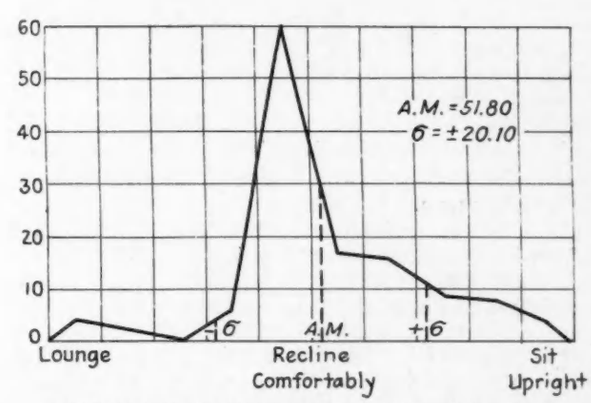


FIG. 10 - MOST DESIRABLE POSITION IN SEAT TO GIVE MAXIMUM COMFORT

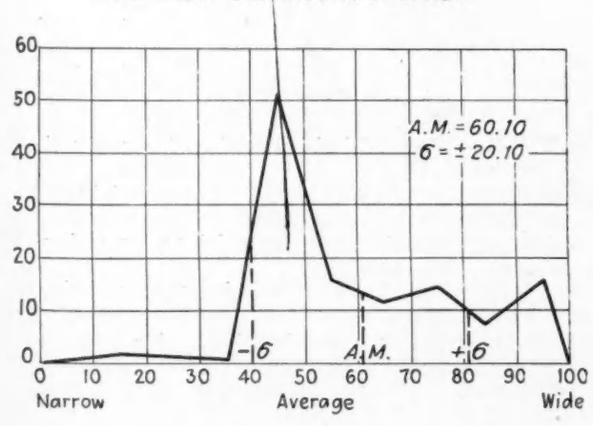


FIG. 11 - DEPTH OF SEAT FROM FRONT TO BACK

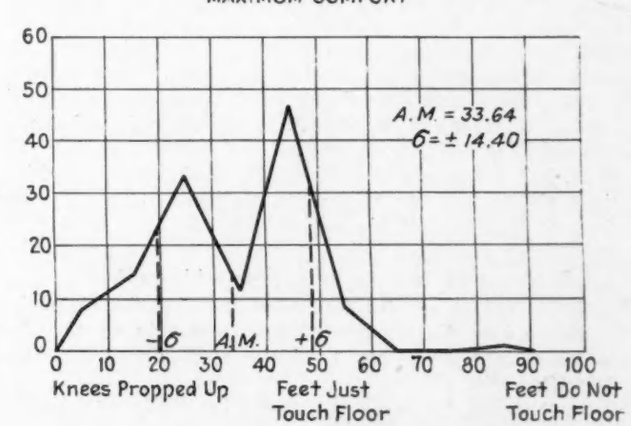


FIG. 12 - HEIGHT OF FRONT OF SEAT FROM FLOOR

TABLE 2—BODY STYLE PREFERRED

	Open		Semi-Closed		Sedan	
	No.	Per Cent	No.	Per Cent	No.	Per Cent
Men	0	0	3	3.7	78	96.3
Women	2	4.3	0	0	44	95.7
Total	2	1.6	3	2.3	122	96.1

TABLE 3—PREFER TO DRIVE WHEN RIDING

	Yes		No		Neutral	
	No.	Per Cent	No.	Per Cent	No.	Per Cent
Men	72	88.9	5	6.2	4	4.9
Women	26	57.7	16	35.6	3	6.7
Total	98	77.7	21	16.7	7	5.6

men feeling more satisfaction from this source than the women.

(12) *Noise from Wind.*—A large standard deviation indicates a wide disagreement. The arithmetic mean in Table 1 indicates some objection to noise from this source. Improvement in exterior body design might be effective.

(13) *Unidentified Noises.*—Noises arising from unknown sources cause anxiety. With a small standard deviation, a low arithmetic mean, with a small probable error, the data are very significant. This item and the one on body squeaks suggest radical changes in chassis and body construction.

(14) *Desirable Amount of Visibility.*—The graph of this item (Fig. 9) shows clearly the emphasis placed on clear vision. The reliability of the arithmetic mean is high. The measure of skewness is −75, which is high. All of the statistical data indicate the necessity of designing the body with the maximum amount of visibility.

(15) *Odors from Engine.*—These are objectionable and produce a feeling of annoyance, as shown by a low arithmetic mean. The standard deviation indicates, however, a low degree of agreement (See Table 1).

(16) *Most Desirable Position in Seat.*—There is a high degree of concentration on this item, the statistical measure indicating that a slightly reclining position is most desirable. In fact, there is a slight tendency to prefer to sit upright rather than to lounge, as shown in Fig. 10.

(17) *Resiliency of Seat.*—The desirability of a highly resilient seat is indicated by the arithmetic mean although the standard deviation indicates a wide spread around the mean.

(18) *Kink of Upholstery.*—Here we find a wide distribution for both sexes, with no significant difference, opinion favoring a deep-pile cloth such as mohair. Cloth is favored over leather.

TABLE 4—RANGE OF AGES, IN YEARS

		Mean of Ages
Men	18 to 51	27
Women	17 to 27	20

(19) *Arm Rests.*—There is a wide range of opinion as to the value of arm rests, ranging from "objectionable" to "very desirable," with very positive attitudes both for and against them.

(20) *Foot Rests.*—There is some agreement favoring foot rests, although again there is a threefold distribution, which is similar for the two sexes.

(21) *Depth of Seat from Front to Back.*—The modal value is located 5 points below the normal position, although the arithmetic mean is 11 points above (See Fig. 11). The skewness is slight and negative. There is a significant sex difference, as indicated in Table 1. The difference of the mean for the two groups is 12.75, the mean for the women falling near the normal. A small group of men favor a very wide seat.

(22) *Height of Front of Seat from Floor.*—The data indicate that the feet must rest squarely on the floor so as to remove some of the pressure from the upper leg (See Fig. 12).

(23) *Body Room: Open Space in Front of Seat.*—A roomy body is desirable, as shown by the arithmetic mean. Freedom of movement of the lower legs contributes to the comfort of the individual.

(24) *Interior Decoration.*—Esthetic appropriateness is desirable, but not highly important to the average person. A small group regards it, however, as very important. There is no significant sex difference.

Table 2 gives the summary of data obtained from the sheet regarding preference as to type of body, and Table 3 the preference as to driving while riding. This plan was followed because it was believed that the information might aid in the interpretation of the data. This is exactly what happened. For example, the large number who prefer to drive when riding probably indicates a confusion in the mind of the rater between riding and driving qualities. The type of car generally used by the rater may also influence his ratings. Twenty-six makes of car were listed in the replies, 35 per cent of the cars being very low priced and the majority of medium price. Significant sex differences are indicated in six of the 24 items of the scale.

Finally, items found in the summary of suggested "other factors" give much additional information for classification and study.

Conclusions Drawn from Study

The following conclusions are given as tentative since they are based on only 125 cases. In view of the data presented in the tables, the following statements seem warranted:

(1) Vertical motion, swaying motion and skidding are undesirable. Vertical motion is most annoying of all

(2) Noises from various sources are very annoying. Body squeaks are particularly objectionable.

(3) As complete and as clear visibility as possible is highly desirable

(4) The position and freedom of movement of the rider's body in the car are very important

(5) The design of the seat is important in the riding-qualities of a car

(6) There are significant sex differences with regard to (2) Swaying motion, (3) Skidding, (5) Acceleration, (6) Retardation, (11) Noise from Tires, and (21) Depth of Seat from Front to Back

(7) The sedan type of body is preferred almost universally

(8) Rubber floor covering in front and carpet in the rear are definitely preferred

(9) The majority of men prefer to drive when riding. More than one-half of the women prefer to drive when riding. There is some confusion between riding and driving qualities

(10) Noise from any source is objectionable

(11) The comfortable qualities in riding are often mental. Fatigue may be due to those mental qualities as well as to bodily discomfort

It must finally be admitted (*a*) that the results se-

cured through this investigation are based on too limited a number of cases and (*b*) that the rating scale used is too crude to make our conclusions more than faint arrows pointing in certain directions. We believe, however, that our method will, with further refinement and more extensive use, produce some useful and valid data on the problems.

In addition to the work described in this paper, we have partly designed an instrument for measuring effects of various motions on visual acuity. We think this will be of material assistance in checking up on subjective judgments. We have also designed and made a steadiness-testing device which we hope to use as a further check on our subjective measures.

Our next step, as we see it, should be the application of such techniques as we have developed to several hundred subjects under actual riding conditions. If the members of the Committee feel that we may reasonably hope to produce worthwhile results, we shall attempt to continue the study throughout the next school year.

What About Inventions?

(*Concluded from p.* 304)

get around some of the technical details of the references cited, but in general the full principle was finally allowed, taking some four or five actions by the Patent Office and often as many years. If a person or a small corporation is carrying the burden, or if a few friends are helping to carry a proposition through, this delay is extremely annoying. These cases, I think, necessarily must take somewhat longer than the simple cases, but such extended delay seems unnecessary.

As to the examiners, I suppose the younger men are not paid enough to stay there for any great length of time, and we are up against new men more or less all the time. They select a couple of pictures that, to them, seem to embody the idea and send the application back which means a delay of 6 or 8 months. I do not know if the Society can do anything directly about the situation, but it certainly bears down heavily on the inventor in delaying matters.

Vapor-Locking Tendencies of Fuel-Systems

(*Concluded from p.* 354)

the American public went through that a few years ago, and I wonder if drivers would care to go back to an additional complication involving pressure leaks, broken tubes, control cables and what not.

P. J. KENT[11]:—Mr. Wilkin asked about service remedies for the older cars. I might offer a suggestion. Occasionally, when new cars are taken on experimental trips into hot countries and have trouble from vapor lock, usually the first thing tried out in the field is to erect a metal shield so as to deflect the hot air from the exhaust pipe away from the carbureter or the fuel pump. This simple remedy might be worth while, from a service point of view, on some of the older cars.

B. B. MEARS:—Would it help any to draw the air from the driver's compartment of the cowl instead of from the front of the hood?

CHAIRMAN BACHMAN:—It might, provided we did not have an occasional backfire.

[11] M.S.A.E.—Chief electrical engineer, Chrysler Motors, Birmingham, Mich.

International Road Congress

INTERESTING, directly or indirectly, to all members of the Society is the announcement that the Sixth International Road Congress will be held in the City of Washington, at the invitation of the United States Government, opening on Monday, Oct. 6, and closing on Saturday, Oct. 11. Never before has the Congress convened in this country, the five earlier meetings having taken place in Paris in 1908, Brussels in 1910, London in 1913, Seville in 1923 and Milan in 1926.

Roy D. Chapin is president of the American Organizing Commission, which is responsible for all arrangements for the event. The Congress, which is technical in character and not commercial, is a medium for the interchange of the world's best opinions on social, economic, financial, administrative and operating phases of highway and motor transportation. It will be truly international in attendance, as 47 nations have officially agreed to participate.

Many American engineers and economists undoubtedly will want to take part. Individuals or groups may be enrolled as members of the Permanent International Association of Road Congresses. Membership in the Association, whether of an individual or of a group, may be permanent or temporary, as desired. All members of the Society who are interested in the work of the Association and who would like to attend the Congress in Washington next month are urged to write immediately to Thomas H. MacDonald, Secretary General, American Organizing Commission, 1723 N Street, N. W., Washington, D. C.

Mr. MacDonald will furnish the necessary information regarding the program, the different classes of membership and the dues for each class, and will send the application blanks that must be filled out by all who apply for membership, of whatever class.

All classes of members are entitled to whatever special transportation rates may be established for attendance at the Congress. If enrolled one month before the opening, they will receive, previous to the convening of the Congress, the official papers on the subjects indicated in the program.

In addition to the interesting program that has been arranged, the American Road Builders Association is planning a very comprehensive exposition of road-building methods and machinery in conjunction with the congress.

Standardization Progress

Aircraft Division Reports

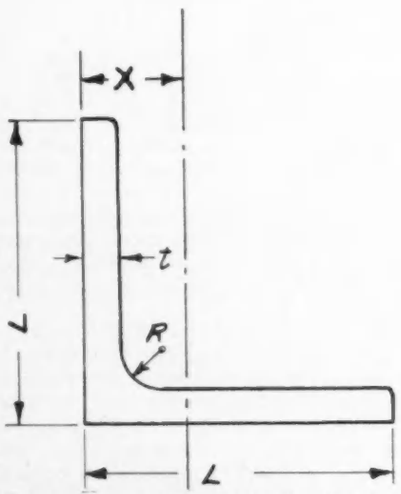
Extruded Shapes, Rivets, Bolts and Nuts, Washers Shock-Absorber Strut Ends and Tires

A MEETING of the Aircraft Division of the Standards Committee was held at the Palmer House, Chicago, on Tuesday, Aug. 26. The Division heard and acted upon reports of the several Subcommittees. As a result of the thoroughness with which these reports were prepared, they were in general accepted as prepared, and the minutes of the action taken will be circulated to members of the Division for a mail vote.

A series of extruded duralumin structural shapes, evolved for particular application to the aircraft industry, was approved as recommended practice. It is the belief of the Division that these specifications will assist in clarifying the present utilization of these structural shapes, in that the series gives a complete range of normally used sizes and shapes from which design selection may be made, and possibly prevent the introduction of special designs.

EXTRUDED ALUMINUM-ALLOY BULB ANGLES

Size	L_1	L_2	t	a	D	R	Area	Moment of Inertia	Section Modulus	Radius of Gyration	I_{2-2}	X	Weight per Foot
15/16	15/16	5/8	0.063	0.063	0.188	0.094	0.12518	0.01289	0.02231	0.321	.....	0.367	0.150
1 1/8	1 1/8	3/4	0.075	0.063	0.225	0.112	0.17111	0.02475	0.03671	0.381	.....	0.451	0.205
1 5/16	1 5/16	7/8	0.088	0.063	0.264	0.132	0.19700	0.04333	0.06273	0.469	0.005196	0.630	0.236
1 1/2	1 1/2	1	0.100	0.070	0.300	0.150	0.2544	0.07222	0.09211	0.533	0.00866	0.716	0.305
1 7/8	1 7/8	1 1/4	0.125	0.088	0.375	0.188	0.3975	0.17621	0.17989	0.666	0.02113	0.895	0.477
2 1/4	2 1/4	1 1/2	0.150	0.105	0.450	0.225	0.5724	0.56560	0.31087	0.799	0.04384	1.074	0.687
3	3	2	0.200	0.140	0.600	0.300	1.0176	1.15549	0.73688	1.066	0.13856	1.432	1.220



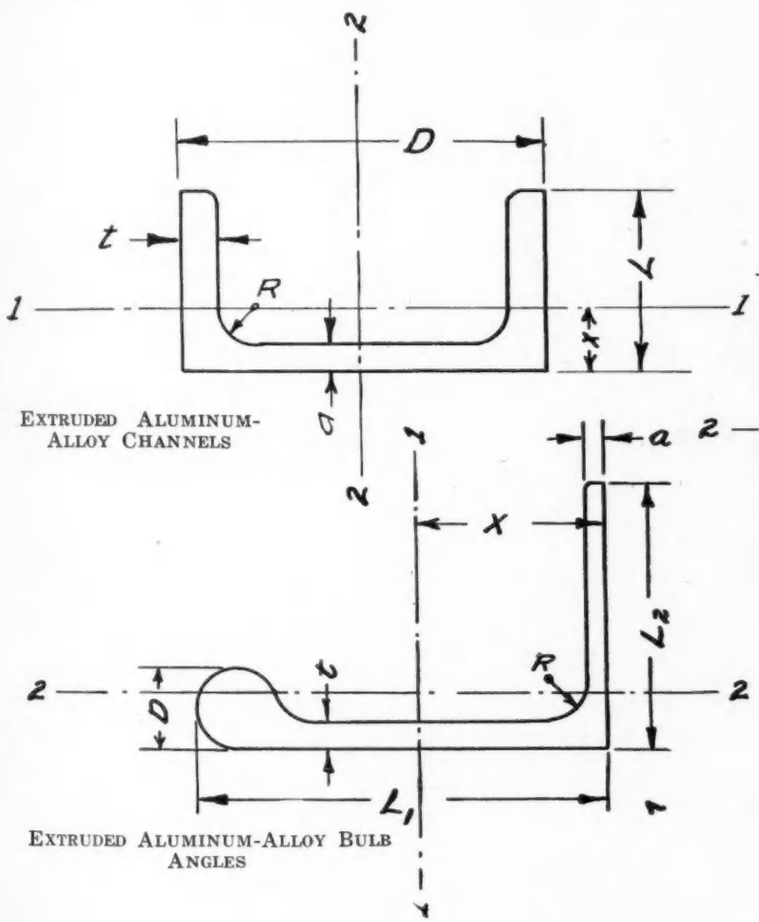
EXTRUDED ALUMINUM-ALLOY EQUAL ANGLES

EXTRUDED ALUMINUM-ALLOY EQUAL ANGLES

Size	t	L	R	X	Area	Moment of Inertia	Section Modulus	Weight per Foot	Radius of Gyration	Least Radius of Gyration
5/8	0.063	5/8	0.063	0.181	0.0763	0.002843	0.006325	0.092	0.194	0.123
3/4	0.075	3/4	0.075	0.215	0.1081	0.005711	0.01068	0.130	0.231	0.147
7/8	0.088	7/8	0.088	0.253	0.1488	0.01083	0.01723	0.178	0.272	0.172
1	0.100	1	0.100	0.287	0.1922	0.01805	0.0253	0.231	0.309	0.195
1 1/4	0.125	1 1/4	0.125	0.359	0.3003	0.04404	0.04941	0.360	0.386	0.244
1 1/2	0.150	1 1/2	0.150	0.431	0.4324	0.09138	0.08539	0.520	0.463	0.293
2	0.200	2	0.200	0.574	0.7688	0.2888	0.2024	0.922	0.617	0.391

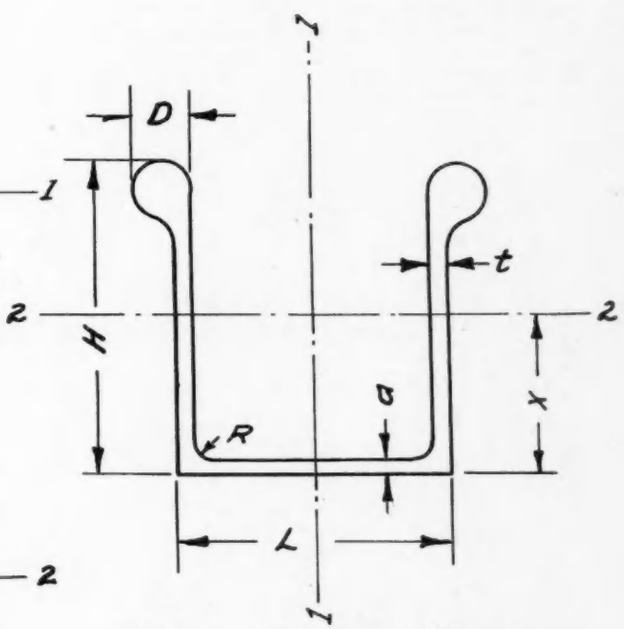
EXTRUDED ALUMINUM-ALLOY CHANNELS

Size	L	D	t	a	R	x	Area	I_{1-1}	S_{1-1}	K_{1-1}	I_{2-2}	S_{2-2}	K_{2-2}	Weight per Foot
¾	⅜	¾	0.063	0.063	0.063	0.117	0.08902	0.001119	0.004308	0.112	0.007195	0.019035	0.290	0.107
⅞	7/16	⅞	0.063	0.063	0.063	0.132	0.10490	0.001836	0.005950	0.132	0.011823	0.026808	0.336	0.126
⅞	7/16	⅞	0.088	0.061	0.088	0.150	0.12414	0.002265	0.007811	0.135	0.014345	0.3257	0.340	0.149
1	½	1	0.100	0.070	0.100	0.171	0.16030	0.003775	0.011470	0.153	0.023909	0.04782	0.386	0.192
1¼	⅝	1¼	0.125	0.088	0.125	0.214	0.25047	0.009211	0.022401	0.192	0.058338	0.09339	0.482	0.301
1½	¾	1½	0.150	0.105	0.150	0.257	0.36067	0.028322	0.038711	0.230	0.121039	0.16139	0.579	0.433



EXTRUDED ALUMINUM-ALLOY CHANNELS

EXTRUDED ALUMINUM-ALLOY BULB ANGLES



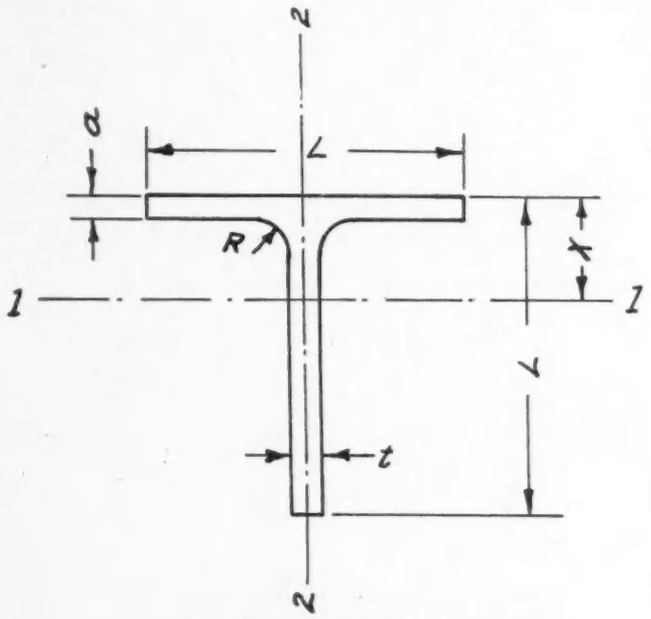
EXTRUDED ALUMINUM-ALLOY BULB CHANNELS

EXTRUDED ALUMINUM-ALLOY BULB CHANNELS

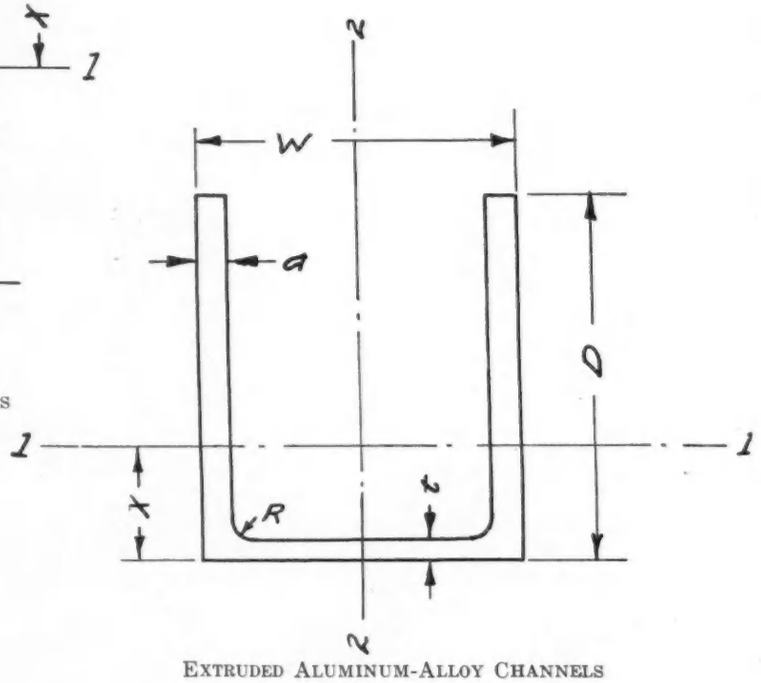
Size	L	D	t	h	a	R	x	Area	I_{1-1}	S_{1-1}	K_{1-1}	I_{2-2}	S_{2-2}	K_{2-2}	Weight per Foot
1	⅞	3/16	1/16	1	1	1/16	0.464	0.21671	0.033059	0.060735	0.390	0.028629	0.05049	0.363	0.260
1¼	1 3/32	15/64	5/64	1¼	5/64	5/64	0.574	0.33219	0.077663	0.115288	0.484	0.067255	0.09584	0.450	0.399
1½	1 5/16	9/16	3/32	1½	0.070	3/32	0.728	0.45594	0.16108	0.20755	0.594	0.13117	0.15505	0.537	0.547
1¾	1 17/32	21/64	7/64	1¾	0.082	7/64	0.844	0.61306	0.29121	0.32359	0.689	0.23715	0.24174	0.622	0.736
2	1¾	⅜	1/8	2	3/32	1/8	0.968	0.80625	0.50337	0.48802	0.790	0.40992	0.36457	0.714	0.968

EXTRUDED ALUMINUM-ALLOY TEES

Size	t	L	a	R	X	Area	I_{1-1}	S_{1-1}	K_{1-1}	I_{2-2}	S_{2-2}	K_{2-2}	Weight per Foot
¾	0.075	¾	0.063	0.075	0.224	0.1012	0.005565	0.01057	0.235	0.002246	0.00599	0.149	0.121
1	0.100	1	0.070	0.100	0.314	0.1673	0.01694	0.02471	0.318	0.006935	0.01387	0.204	0.201
1¼	0.125	1¼	0.088	0.125	0.393	0.2614	0.04133	0.04826	0.398	0.01692	0.02709	0.254	0.314
1½	0.150	1½	0.105	0.150	0.472	0.3764	0.08576	0.08340	0.477	0.03511	0.04681	0.305	0.452
1¾	0.175	1¾	0.123	0.175	0.550	0.5124	0.15888	0.13242	0.557	0.06504	0.07433	0.356	0.615
2	0.200	2	0.140	0.200	0.629	0.6692	0.27104	0.19768	0.636	0.11096	0.11096	0.407	0.803



EXTRUDED ALUMINUM-ALLOY TEES



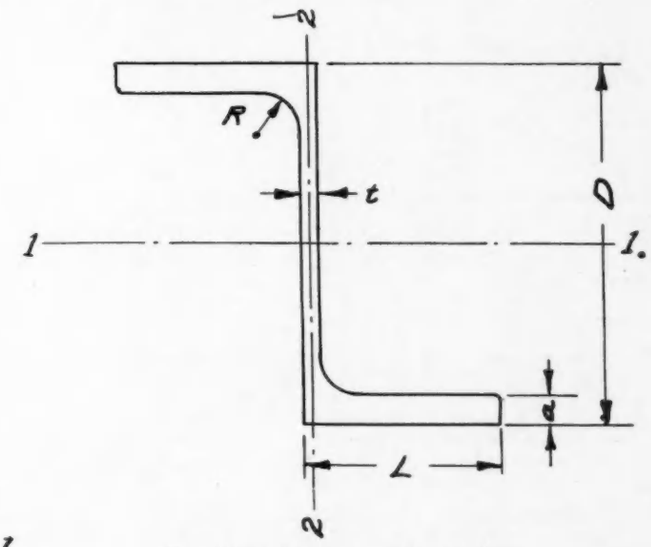
EXTRUDED ALUMINUM-ALLOY CHANNELS

EXTRUDED ALUMINUM-ALLOY CHANNELS

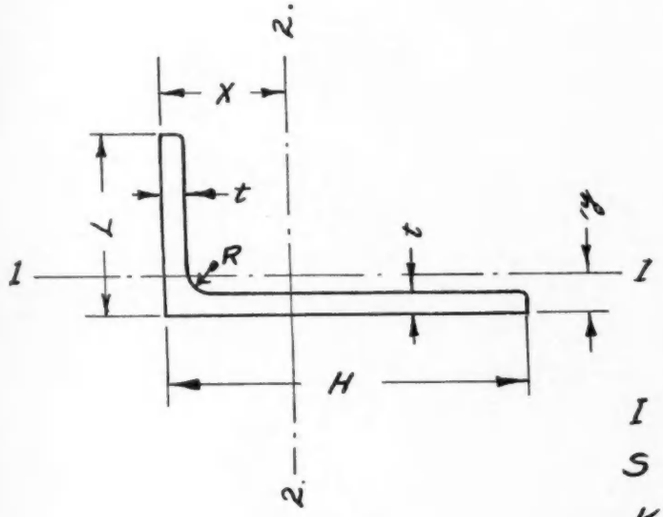
Size	W	D	t	a	R	x	Area	I_{1-1}	S_{1-1}	K_{1-1}	I_{2-2}	S_{2-2}	K_{2-2}	Weight per Foot
1	⅞	1	0.063	0.077	0.063	0.317	0.20016	0.02208	0.03194	0.332	0.02382	0.05402	0.345	0.240
1¼	1 3/32	1¼	0.078	0.094	0.078	0.392	0.30682	0.05186	0.06063	0.411	0.05597	0.10253	0.427	0.368
1½	1 5/16	1½	0.094	0.113	0.094	0.473	0.44560	0.10944	0.10613	0.495	0.11811	0.17948	0.515	0.535
1¾	1 17/32	1¾	0.109	0.131	0.109	0.548	0.59916	0.19785	0.16546	0.574	0.21352	0.27984	0.597	0.719
2	1¾	2	0.125	0.150	0.125	0.629	0.78797	0.34199	0.24953	0.659	0.36908	0.42202	0.685	0.946

EXTRUDED ALUMINUM-ALLOY ZEES

Size	L	D	t	a	R	Area	I_{1-1}	S_{1-1}	K_{1-1}	I_{2-2}	S_{2-2}	K_{2-2}	Weight per Foot
7/8	1/2	7/8	0.063	0.063	3/32	0.1150	0.01340	0.03038	0.341	0.00446	0.01012	0.197	0.138
1	9/16	1	0.063	0.080	0.125	0.1510	0.02375	0.04713	0.397	0.00824	0.01538	0.234	0.181
1 1/4	11/16	1 1/4	0.063	0.100	0.125	0.2132	0.05500	0.08730	0.508	0.01947	0.02943	0.302	0.256
1 1/2	0.825	1 1/2	0.075	0.120	0.150	0.3022	0.11049	0.14736	0.604	0.03911	0.04968	0.360	0.363
1 3/4	0.963	1 3/4	0.088	0.140	0.175	0.4160	0.20952	0.23780	0.709	0.07416	0.08017	0.422	0.499
2	1.10	2	0.100	0.160	0.200	0.5372	0.34920	0.34920	0.806	0.12360	0.11772	0.480	0.645
2 1/2	1 3/8	2 1/2	0.125	0.200	0.250	0.8394	0.85206	0.68199	1.007	0.30160	0.22991	0.600	1.007
3	1.65	3	0.15	0.240	0.300	1.2087	1.76785	1.17855	1.209	0.62575	0.39730	0.720	1.450



EXTRUDED ALUMINUM-ALLOY ZEES



-: NOTE :-

I MOMENT OF INERTIA

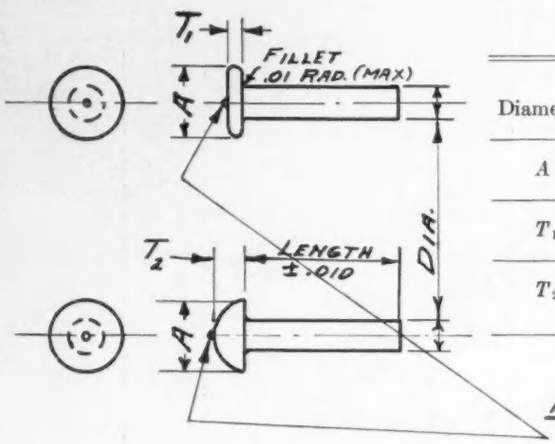
S = SECTION MODULUS

K = RADIUS OF GYRATION

EXTRUDED ALUMINUM-ALLOY UNEQUAL ANGLES

EXTRUDED ALUMINUM-ALLOY UNEQUAL ANGLES

Size	L	h	t	R	x	y	Area	I_{1-1}	S_{1-1}	K_{1-1}	I_{2-2}	S_{2-2}	K_{2-2}	Weight per Foot
1/2 x 1	1/2	1	0.063	0.063	0.357	0.108	0.09216	0.001700	0.004290	0.136	0.009766	0.015007	0.326	0.111
5/8 x 1 1/4	5/8	1 1/4	0.078	0.078	0.442	0.133	0.14127	0.003994	0.008142	0.168	0.022943	0.028484	0.403	0.170
3/4 x 1 1/2	3/4	1 1/2	0.094	0.094	0.533	0.161	0.20517	0.008429	0.014253	0.203	0.048415	0.049861	0.486	0.246
7/8 x 1 3/4	7/8	1 3/4	0.109	0.109	0.618	0.186	0.27588	0.015238	0.022222	0.235	0.087529	0.077739	0.564	0.331
1 x 2	1	2	0.125	0.125	0.709	0.214	0.36281	0.026340	0.033513	0.270	0.151297	0.117239	0.646	0.435
1 1/4 x 2 1/2	1 1/4	2 1/2	0.156	0.156	0.884	0.267	0.56508	0.063932	0.065146	0.337	0.367230	0.227898	0.806	0.678



ALUMINUM-ALLOY RIVETS

Diameter	1/16 +0.003 −0.001	3/32 +0.003 −0.001	1/8 +0.0035 −0.001	5/32 +0.004 −0.001	3/16 +0.004 −0.001	1/4 +0.004 −0.001	5/16 +0.004 −0.001	3/8 +0.004 −0.001
A	1/8 ±0.006	3/16 ±0.009	1/4 ±0.012	5/16 ±0.016	3/8 ±0.019	1/2 ±0.025	5/8 ±0.031	3/4 ±0.037
T_1	0.025 ±0.005	0.038 ±0.005	0.050 ±0.005	0.062 ±0.005	0.075 ±0.005	0.100 ±0.005	0.125 ±0.005	0.150 ±0.007
T_2	0.047 ±0.005	0.070 ±0.005	0.094 ±0.005	0.117 ±0.005	0.141 ±0.007	0.188 ±0.009	0.234 ±0.012	0.281 ±0.014

HEADS OF ALL RIVETS TO HAVE RAISED PIMPLE FOR IDENTIFICATION

ALUMINUM-ALLOY RIVETS

Diameter	LENGTH																			
	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4	2	2 1/2	3	3 1/2	4
1/16	X	X	X	X	X	X	X	X	X	X	X	X								
3/32	X	X	X	X	X	X	X	X	X	X	X	X	X							
1/8	X	X	X	X	X	X	X	X	X	X	X	X	X	X						
5/32		X	X	X	X	X	X	X	X	X	X	X	X	X	X					
3/16		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
1/4				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
5/16						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
3/8							X	X	X	X	X	X	X	X	X	X	X	X	X	X

ALUMINUM RIVETS

Diameter	LENGTH														
	3/16	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 3/4
1/16	X	X	X	X	X	X									
3/32	X	X	X	X	X	X	X	X							
1/8		X	X	X	X	X	X	X	X	X	X	X			
5/32			X	X	X	X	X	X	X	X	X	X			
3/16			X	X	X	X	X	X	X	X	X	X	X	X	
1/4					X	X	X	X	X	X	X	X	X	X	X

Aluminum and Aluminum-Alloy Rivets

Standards for aluminum and aluminum-alloy rivets of the flat and round-head types conforming to the present generally accepted commercial and military practice, were approved. The Subcommittee still has under advisement the matter of standards for other types of rivet, such as countersunk head, button head, mushroom head and brazier head.

Bolts and Nuts

Additional standards for ¾, ⅞ and 1-in. aircraft bolts and nuts were approved. The tolerance in nominal diameter has been reduced in conformity with a similar reduction in the AN Standards.

The Division further recommended that the nominal diameter of the aircraft bolts be reduced by 0.001 in.; that is, the nominal diameter of the ¼-in. bolt would be 0.249 in., with limits of plus 0.000, minus 0.003. This would enable the airplane manufacturer to use a standard ¼-in. reamer for finishing the hole in the fitting.

Under the present scheme with a nominal dimension of 0.250 in., the hole must be made at least 0.251 in., which requires the use of a special reamer or an expansion reamer. The objections to either special reamers or adjustable reamers are believed sufficiently obvious to warrant this change at this time.

Tires

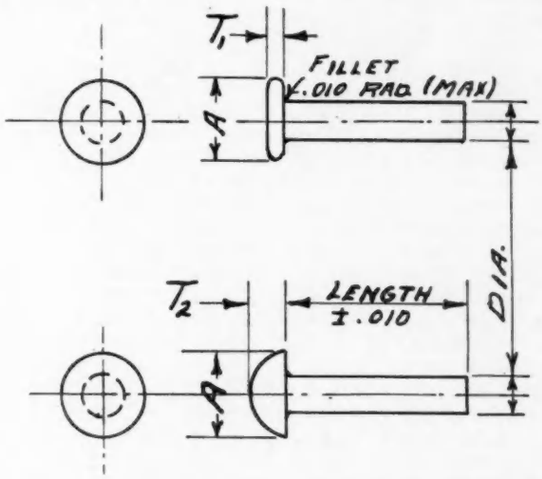
The addition of the 12 x 4-in. tire, as set up in the Tire and Rim Association Yearbook, to the S.A.E. Recommended Practice was approved.

Bevel Washers

Elimination of the present Recommended Practice for bevel washers, as shown on p. 58 of the 1930 edition of the HANDBOOK, was recommended, as the use of these has become virtually obsolete practice.

ALUMINUM RIVETS

Diameter	$\frac{1}{16}{}^{+0.003}_{-0.001}$	$\frac{3}{32}{}^{+0.003}_{-0.001}$	$\frac{1}{8}{}^{+0.0035}_{-0.001}$	$\frac{5}{32}{}^{+0.004}_{-0.001}$	$\frac{3}{16}{}^{+0.004}_{-0.001}$	$\frac{1}{4}{}^{+0.004}_{-0.001}$	$\frac{5}{16}{}^{+0.004}_{-0.001}$	$\frac{3}{8}{}^{+0.004}_{-0.001}$
A	$\frac{1}{8}\pm0.006$	$\frac{3}{16}\pm0.009$	$\frac{1}{4}\pm0.012$	$\frac{5}{16}\pm0.016$	$\frac{3}{8}\pm0.019$	$\frac{1}{2}\pm0.025$	$\frac{5}{8}\pm0.031$	$\frac{3}{4}\pm0.037$
T_1	0.025 ±0.005	0.038 ±0.005	0.050 ±0.005	0.062 ±0.005	0.075 ±0.005	0.100 ±0.005	0.125 ±0.005	0.150 ±0.007
T_2	0.047 ±0.005	0.070 ±0.005	0.094 ±0.005	0.117 ±0.005	0.141 ±0.007	0.188 ±0.009	0.234 ±0.012	0.281 ±0.014



Shock-Absorber Strut Ends

Detailed dimensional standards for shock-absorber strut ends were approved as it is felt that there is a distinct need for such a recommended practice, which will assure interchangeability of shock-absorber struts of different manufacture and design.

New Activities

Approved for further activity of the Division were the following: shear units, control sticks, and modernization of the data on instrument mountings. These will be assigned to several Subcommittees for further detail development.

Cleaning Metal for Painting

Paper Presented by F. Palin Spruance[1] at a Meeting of the Pennsylvania Section. It Applies Most Directly but Not Exclusively to Sheet-Metal Automobile Bodies

CLEANING methods which are frequently very elaborate have been adopted by the entire automobile industry, and today every finisher realizes that suitable results cannot be obtained unless the metal is clean, chemically as well as mechanically, before it is primed. Paint failures were encountered everywhere in the days before adequate cleaning methods were adopted, and they were so serious that the future of the steel body was despaired of and great financial losses were sustained by the body manufacturers because of the development of defects in the finish which led to its untimely failure. The quality of the paint was usually blamed, in those days, and few builders were farsighted enough to correctly attribute the failures to the improper preparation of the metal to receive the paint.

Before describing satisfactory methods for preparing metal surfaces for finish that have been gradually developed out of the chaos of 1910 to 1915, we shall consider some of the causes of paint failure to discover where these causes are encountered in the fabrication of the sheet-metal parts.

Rust and the chemicals that produce it and accompany it are without doubt the most serious offenders. Second to them may be placed such things as oil, graphite, grease, lacquer, friction paste and dried paint. Third come alkalis. Fourth are those miscellaneous foreign materials—which, for want of a better name, we can call dirt—that must be removed if a smooth, unbroken finish which will exclude atmospheric rusters is to be obtained.

Inert Rust Is Harmless

Rust itself, if it is possible without the prolific breeders that produce it, is not harmful. Materials similar to it are used as pigments in our best primers. The danger of dust lies rather in the presence of the rust-forming chemicals that produce and accompany it and which will, unless removed or destroyed, set up a continuous rusting cycle under coats of oil or paint. The removal of rust is therefore looked upon as necessary today, not only to remove roughness in an otherwise smooth surface but principally so that the invisible chemicals beneath the surface coating can be prevented from continuing their destructive cycle. However, the day is probably not far off when plant chemists and painters will differentiate between active rust, accompanied by rust-producing chemicals, and inert rust, in which the rust breeders have been completely destroyed; and without doubt they will consider it safe to prime over inert rust if it is not too rough, with no other effect than to slightly increase the pigment in the primer.

Rust-forming chemicals, which under favorable conditions produce rust, are encountered at various stages in the fabrication of the sheet-metal products, starting as far back as the pickling of the sheets or strip in the steel mill. Here the hot-rolled sheets are pickled, to remove the mill scale, in a bath of sulphuric acid, an active ruster. After what usually amounts to an almost futile attempt to neutralize the pickling acid, they are washed in muriatic acid to remove a light rust coating that is due to the incompleteness of this neutralization. Muriatic acid is a worse ruster, if possible, than the sulphuric acid that is used to remove the scale. To be sure, the sheets are removed from the muriatic acid and washed in water, and they are scrubbed with brushes and dried over a gas flame or a coke fire before they are cold rolled; but this treatment cannot suffice to remove or neutralize either of the rust-forming acids, which are left on the sheet as it comes from the mill and will cause rust to develop when the conditions become favorable.

In addition to these active rusters, that are embedded in the surface of the sheet in the mill, there are alloying materials or impurities in the steel itself which stimulate rust.

Rust does not develop immediately, because the sheets are kept dry until the oil coating is applied, and during shipment and storage; but it should be remembered that these clean-looking sheets have rust producers on them that must be counteracted before they are covered with the finish coats.

Soldering Is Chief Cause of Rust

Perhaps the next attack of rusters is encountered during the handling of the sheets or formed panels in the press shop, where some of the mill oil is removed and where perspiration from the workmen's hands and probably acid fumes from a nearby pickling tank are deposited on the metal. The most serious ruster, however, is encountered wherever any soldering is done. Soldering acids, salts or pastes, consist essentially of zinc chloride, a deliquescent salt, and all of them that are suitable for soldering steel are active rusters. They form iron chloride, which when acted upon by the air is changed into hydrated iron oxide or rust.

Zinc chloride fluxes are effective on steel only if it is free from scale or rust. If these are present, they must first be removed before the surface can be properly tinned. The scale and rust coatings could of course be removed with a file or an abrasive wheel if the surface were smooth, but the surface is usually so irregular that embedded scale could not be removed without grinding entirely through parts of the sheet. It is therefore necessary either to remove any scale or rust prior to the application of the zinc chloride flux or to combine a cleaning acid with the flux.

The former practice was to pre-clean with muriatic acid, known in shop parlance as raw acid. This liquid volatilizes at room temperature and much more rapidly with the heat of a soldering iron or torch. Both the liquid and the gas that come from it produce rust; and the vapors may be blown some distance and cause rust on any steel, particularly if free from oil, with which it comes in contact.

Muriatic acid penetrates the surface of steel rapidly and sets up a continuous rusting cycle. If rust from this cause is to be prevented it is necessary to remove or destroy all of the muriatic acid and its salts. It is obvious that it can neither be removed nor destroyed by any treatment which is confined to the surface or which might serve to dilute the acid. To neutralize the acid with an alkali will not suffice, for the resulting salts are themselves rust producers and must be removed.

Solvents Do Not Remove All Oil

The second class of materials to be removed includes oils, graphite, drawing compounds and greases. Oil is applied to the sheets at the mill, and more oil and various greases are applied to the blanks on the press to fa-

[1] A.S.A.E. — Sales Manager, American Chemical Paint Co., Ambler, Pa.

cilitate the drawing. Materials of this class are not so harmful in producing rust as in the effect they have on the finishing coats and the tendency to include within themselves or to cover rusters and to hinder their removal.

Thick coatings of oil tend to prevent good paint adhesion, even with long oil primers, and complete removal of oil is of utmost importance with the quick-drying undercoats that are now looked upon with increasing favor. Dried paints and hardening oils, too frequently used in paddling solder, often seal over rusters that are consequently allowed to remain after the cleaning.

Petroleum fractions and various other solvents have long been looked upon as a satisfactory means for removing slushing oils and lubricants, but their ineffectiveness is conclusively proved by running water onto steel that is supposedly freed of oil by this method and observing the breaks in the water film which are caused by traces of oil. Alkaline baths and solutions are no more effective than the solvent detergents. In addition to not removing the oil films completely, these have the disadvantage of being less volatile and of leaving a coating of alkali on the surface that constitutes the third group of objectionable materials which should be removed.

The presence of even a trace of alkali is highly objectionable on surfaces that are to be enameled; even the negligible amounts present in the city water will cause alkali spots to develop, particularly during the humid months or in damp localities. Though the quantities of alkali are too small to be detected readily, their presence will soon become evident through the enamel film.

In the fourth group are miscellaneous materials, such as specks of solder, iron filings, grit from abrasive papers, sawdust, paint spatters and anti-squeak which find their way onto the panels in passing along the construction line. These must all be removed if a smooth, continuous coating of primer is to effectively seal the cleaned surface.

This enumeration of the various substances, differing widely in chemical composition, which have to be removed before a surface can be considered fit to paint, suggests that the problem of supplying a cleaner which will dispose of all this extraneous matter is not simple, but it has been attacked from a scientific angle and solved in a very simple and satisfactory manner.

The cleaner should (*a*) remove oil, grease and anti-squeak, so that the entire metal surface can be acted upon; (*b*) remove rust and destroy all rusters; (*c*) remove alkalis and destroy their paint-shedding action; and (*d*) produce a surface to which the prime coat will adhere tightly.

Prior to the adoption of the processes that fulfilled these requirements, sheet metal was inflicted with all sorts of treatments and medications. The sand blast was at one time looked upon with great favor; but it was costly and dirty and buckled the body panels. It had little or no effect in preventing rust, though it did remove rust coatings from the surface, because it left the rusters beneath the surface. The ineffectiveness of the sand blast as a rust preventive led up to the treatment of surfaces with such remedies as vinegar and stale beer.

When the all-steel body free from solder was developed, it was heated in a burn-off oven to a temperature high enough to blue the steel; but—even without soldering acid, the most active rust producer—the results were not altogether satisfactory. Most of the solvents, alkalis, and other reagents from a well-stocked laboratory were tried. But rust was almost universal; and bodies that were rejected and returned to the paint room, when stripped and refinished, almost invariably rusted again. In 1912 I saw steel bodies that were returned to the manufacturer refinished as many as five times—and they are still rusting.

Solution Found by Chemist

It remained for George D. Feidt, in 1914, to take from the shelf of his laboratory a bottle of phosphoric acid and mix with it some alcohol to produce a cleaning medium which laid the foundation for the processes that have been used most successfully ever since. The cleaning material — essentially phosphoric acid and alcohol, exploited under the trade name of Deoxidine by the American Chemical Paint Co.—is the Feidt material, with improvements and additions which have made it more economical or better suited to various production requirements. Its success is due to the fact that, while alcohol alone will not remove the oil film from the metal completely, the combined action of phosphoric acid and alcohol has a surprising effect in removing both oil and rust.

Rust is removed almost as rapidly with phosphoric acid as with muriatic or sulphuric acid, but the great advantage of phosphoric acid is that the products of the reaction are beneficial rather than detrimental and it is not too expensive to use commercially. The visible rusters are removed and also those that are invisible at the time of cleaning are eradicated and rendered harmless. Oil is removed more completely by this method than by any other commercial one I know of; alkalis are destroyed, and a slightly etched and passive surface is produced.

In the original wet Deoxidine process, as applied at present to the cleaning of automobile bodies, the bodies are first prepared for the cleaning by removing the dust, shavings and chips by a compressed-air jet. Next, paint spatters, from slushing the inside of the body; anti-squeak, used in the joints; lacquer, used under moldings; and hardening oils, if they are used in torch soldering, must be removed in a pre-cleaning operation by petroleum fraction and suitable solvents, as the chemical will not remove dried paint.

Then the bodies pass onto a deck, having a draining acid-proof floor, where the chemical is applied, for a production of 30 or more bodies per hour, by two dopers using large special brushes. Approximately one-half of the chemical can be reclaimed. As the bodies are carried along the line, the next two men scrub the entire surface, while it is still wet, with large bundles of steel wool, to break up any oil film, scrubbing soldered areas and acid runs.

Washing can be done most satisfactorily with a sponge and cold water from a hose. This is followed by a rinsing in hot water and wiping with cloths that are wrung dry. Air is used to blow moisture from joints and behind moldings. Oven drying is followed by wiping with a rag dipped in alcohol or alcohol and water, which is combined with inspection and final cleaning of any areas that have been skipped in the previous treatment. The total cost for labor and cleaner approximates 50 to 90 cents per body and 5 to 8 cents for supplies such as steel wool, alcohol, rubber gloves and boots.

Various Chemical Cleaning Processes

Other processes and chemicals have been developed for reducing the amount of rust formed during soldering and for removing the rusters immediately after the soldering operations, before etching has resulted. Such cleaning is known as the dry process, and it will not remove heavy grease or pitted rust that can be removed in the wet process. It is applicable with economy where only occasional light rust is present and very little paint, anti-squeak and the like are to be removed. This process is particularly satisfactory as a preparation for quick-drying priming and surfacing materials, because the powdered coating that is used removes oil very thoroughly from seams and other places from which it might seep out after the primer is applied.

A semi-dry process has been developed, in which the rinsing operation required in the wet-cleaning process is eliminated. This is used under conditions where the requirements of the cleaning material are less exacting and the cost is exceedingly low.

I cannot urge too strongly the economy of neutralizing the principal rusters immediately after soldering. The cost of this is but a fraction of the cost of removing heavy rust, and the rusters can be destroyed much more completely before they have eaten their way into the metal.

Production Meeting Well Manned

NAMES of the session chairmen and principal speakers who are to participate in the Ninth Annual Production Meeting of the Society, to be held in the Book-Cadillac Hotel, Detroit, Oct. 7 and 8, are a sufficient guarantee that the meeting will be among the best. Perhaps the headliners are J. A. Bohannon, president of the Peerless Motor Car Co., and Gordon Lefebvre, vice-president of the Oakland Motor Car Co., who preside at two of the sessions, and Charles Erwin Wilson, who has grown up through the Delco-Remy organization to become vice-president of the General Motors Corp. and will be the principal speaker at the banquet.

Topics selected by the Production Meetings Committee for the papers to be presented are those upon which production men are seeking all possible light right now, and they are being handled in a way to be helpful both to those whose production is in large quantities and to those whose production is smaller, and to apply to the manufacturers of a large variety of mechanical units and products.

The full program of the meeting will be found below. Most of the papers will be available in preprint form, and members and others who are interested may secure copies in advance to enable them to digest the papers, contribute to the discussion and propound related questions to the authors and others who are in attendance.

Visits to two plants in Detroit have been arranged for, the hosts furnishing transportation from and to the Book-Cadillac and providing guides who will be prepared to answer questions. The plants to be visited are the Plymouth plant of Chrysler Motors, where machinery and material-handling methods for large production can be observed, and the forge plant of the Chevrolet Motor Co., which is said to be one of the most advanced forging units in the Country.

By no means the least of the attractions of the meeting is the opportunity to attend the Production Dinner, which is sponsored by the Detroit Section and will include a good meal, a speaker whom we all wish to hear, and entertainment and fun such as have made the meetings of the Detroit Section famous for several years.

National Production Meeting Program

Book-Cadillac Hotel, Detroit

Oct. 7 and 8

Tuesday, Oct. 7

9.30 A. M.—TECHNICAL SESSION

Chairman: J. A. Bohannon

President, Peerless Motor Car Co.

(1) New Developments in Machining Aluminum and Its Alloys—R. L. Templin, Aluminum Co. of America.

(2) Future Developments of Tungsten Carbide as a Cutting Tool—W. H. McCoy, General Motors Corp.

12.00 Noon—ADJOURNMENT FOR LUNCHEON

2.00 P. M.—ECONOMICS SESSION

Chairman: John Younger

Ohio State University

(1) Economic Production Lots—Paul N. Lehoczky, Ohio State University.

(2) The Tool Engineer's Place in Mass Production—O. B. Jones, Detroit School of Applied Science.

Wednesday, Oct. 8

10.00 A. M.—TECHNICAL SESSION

Chairman: Gordon Lefebvre

Vice-President, Oakland Motor Car Co.

(1) Design Elements and Economic Considerations of Material-Handling Systems from the User's Point of View—J. C. Hough, Matthews Conveyor Co.

(2) Wear Allowances and Tolerances on Gages—E. J. Bryant, Greenfield Tap & Die Corp.

12.00 Noon—ADJOURNMENT FOR LUNCHEON

1.30 P. M. Sharp—PLANT VISITS—DETROIT

(a) Plymouth Plant, Chrysler Motors

(b) Forge Plant, Chevrolet Motor Co.

6.30 P. M.—S.A.E. PRODUCTION DINNER

Grand Ball Room, Book-Cadillac Hotel

Host: S.A.E. Detroit Section—Chairman, P. J. Kent.

Speaker: C. E. Wilson, Vive-President, General Motors Corp.

Transportation Meeting, Oct. 22-24

Six Technical Sessions, a Transportation Dinner and Plant Visits To Be Held in Pittsburgh

THE PROGRAM for the three-day National Transportation Meeting to be held at the William Penn Hotel in Pittsburgh on Oct. 22, 23 and 24 is now assuming final form and will be published in the October issue of the S.A.E. JOURNAL. There are to be two technical sessions on the first day, two technical sessions and a Transportation Dinner session on the second day, and a morning session and afternoon inspection visits to a number of local service and maintenance plants in the afternoon of the third day.

Subjects at First Day's Sessions

Arrangements already made include a paper by Carl Stocks, editor of *Bus Transportation*, on Requirements for Performance Indicators and Recording Devices, to be given at the first session on Wednesday, Oct. 22, with written discussion by representatives of several instrument makers.

At the afternoon session H. B. Hewitt, of the Mitten Management, is to present a paper on The Scientific Inspection of Motor-Vehicles in Their Units, and P. V. C. See, of the Northern Ohio Light & Power Co., is to give one on Motor-Vehicle Maintenance To Prevent Road Delays.

The evening session is to be a joint meeting of the S.A.E. Transportation and Maintenance Activity Committee, the Motorcoach and Motor-Truck Activity Committee, the American Petroleum Institute Committee that is studying tractor fifth-wheel connections, and representatives of the trailer manufacturers and fifth-wheel connection manufacturers. This will not be an open general session.

Second Day's Subjects and Dinner

Thursday morning's session is to be devoted to a paper by Austin M. Wolf, consulting engineer, of Newark, N. J., on Practical Mathematics for Determining Tractor Ability, and one by Adrian Hughes, Jr., of the United Railways & Electric Co., on Taking Advantage of Latent Heat in Cooling Water.

A session on education is scheduled for the afternoon, at which Prof. J. W. Trimmer, of the Carnegie Institute of Technology, is to tell How Principles of Economics in Motor-Vehicle Transportation Are Taught at Educational Institutions, and J. S. Lowe, of the Akron Transportation Co., will give a paper on Motor-Vehicle Maintenance Costs Reduced by the Training of Drivers.

The Pittsburgh Section of the Society is to be host at the National Transportation Dinner on the second evening. F. R. Phillips, president of the Philadelphia Co., of Pittsburgh, is scheduled as the principal speaker.

Last Day's Events

Friday morning there is to be a paper on Aluminum Alloys in Commercial Motor-Vehicles, by Frank D. Goll, of the Aluminum Co. of America, and one on Motor-Vehicle Maintenance by the United States Army, written by Lieut.-Colonel Brainerd Taylor, of the office of the Quartermaster General.

Arrangements have been made for inspection visits in the afternoon to the service, repair and rebuilding station of the Gulf Refining Co.; the motor-truck body-building plant of the Auto Truck Equipment Co., which is devoted mainly to custom work of aluminum construction; and the general service, repair and rebuilding plant of the Equitable Auto Co., which specializes in work for large operators of motor-trucks and motorcoaches.

An attempt is being made to find a place on the program for another maintenance paper to be illustrated with motion pictures.

Chicago Aeronautic Meeting

(*Continued from page* 255)

characteristics, said Lieutenant Harper. The forces in a fast, vicious spin are such that pressure distribution on wing sections at very high angles of incidence should be investigated. The wing slot does more work in helping to bring a plant out of a spin than it is given credit for.

Tests on Weight Distribution

Mr. Hovgard's paper was a description of tests conducted at the plant of the Keystone company in an effort to find an easy cure-all for flat spins. By means of ballast that could be shifted to various locations about the center of gravity of the plane, it was found that as weight was added to the center of gravity the rate of rotation was increased until it reached its critical point and went over into a flat spin. Moving the ballast to the wing tips or to the engine and tail made the spin more difficult to start, but with the ballast in the nose and tail the number of normal turns was markedly decreased. With the weights in the center section and bottom of the pontoon, there was no difference in the entry into the spin and the transition from a normal to a flat spin was almost unnoticeable.

Subsequent tests were made on the center-of-gravity location without changing the moments of inertia or static weight but using varying degrees of sweepback, the center of gravity being varied from 40 to 26 per cent of the mean aerodynamic chord. In the most forward position, it was impossible, said Mr. Hovgard, to enter a spin without first increasing the up-lever throw. As the center of gravity was moved forward, the spins were harder to start but recovery from a long spin was unchanged.

When decalage and washout were incorporated in the airplane, the spin was a little easier to start but could not be carried nearly so far. As the rate of rotation increased, said Mr. Hovgard, the force required to hold the stick in the rear position also increased, and when the stick was released the plane snapped out of the spin in about one-half turn.

The most dependable change to remedy spinning characteristics, according to the speaker, is an increase in area of the horizontal tail; an increase of 50 per cent over the original surface reduced the number of turns required for recovery from a flat spin from five to three and one-quarter. An increase of 100 per cent in fin area had very little effect, and raising the horizontal tail surface 32 in. above its normal position had no effect on the spinning characteristics. A positive dihedral of 10 deg. in the horizontal tail reduced the number of turns for recovery from three and one-half to one and one-quarter.

Low-Wing Monoplane Tests

Instead of reading his prepared paper, Mr. Peed gave a very interesting account of investigations of the vicious spinning characteristics of the Eagle Rock Bullet and the attempts to correct them, which was realized in the

thirteenth model developed. With a center of gravity in the low-wing monoplane 2 in. above the highest point of the wing, the airplane had accelerations as high as 4 gravity, he said, and the tail was doing considerable lifting. Calculations showed eventually that the center of gravity should be considerably to the rear with the lifting tail and that this would give an airplane that would not spin at all.

Should Revise Spin Nomenclature

Mr. Joyce narrated some of his experiences with spins in 1918 in France during the war and down to the present time. From these experiences, he is convinced that what seems to be a normal spinning airplane might, under certain conditions, be made to spin abnormally and bring about a delayed recovery. Apparently the manner in which a spin is entered has a great deal to do with its later characteristics. He believes that the expression "flat spin" should be discontinued, because a plane may have reversal of stick forces and delayed recovery with the attitude of the fuselage either horizontal or vertical. Some differentiation should be made, he said, between stable autorotation as applied to a wing cellule and autorotation as applied to a complete airplane. The nomenclature should be revised, as with the high wing-loadings in use today in relation to mass distribution and clean lines, we are getting into various types of spins that are different in their cause and effect. The easiest way to solve the problems is to have the types correctly defined.

Motion Pictures of Air Corps Tests

Mr. Sutton's presentation was in the form of several reels of motion pictures of airplanes in spins made in a series of tests by the Materiel Division of the Air Corps at Wright Field. Preprints of his paper were available, however. The pictures were taken from the ground with a stationary camera having an 17-in.-focus lens. The airplanes were spun through the field of the camera at altitudes ranging from 6000 to 8000 ft. The first pictures were of tests made on the O-2 airplane with changes in the mass distribution and the moments of inertia. The investigators decided to change to a staggered wing with concentration of the mass, and the Douglas Company built another model that has good characteristics and is now in use by the Army. Similar tests were run on the O-1 and it was found that change of the center-of-gravity location has a similar effect as on the O-2 but a much further movement to the rear is required.

Advisory Committee Research Work

The last speaker was Mr. Weick, who described at considerable length the very valuable research work that the National Advisory Committee for Aeronautics is doing in this particular field. One of the greatest advances in research on spinning that have recently been made is the development of a method of accurately measuring just what an airplane does in a spin; that is, its path of flight and its attitude at each point in the spin. The rates of rotation about the three principal axes are measured by means of three gyroscopic turn-meters, the accelerations about the same axes by means of a three-component accelerometer placed at the center of gravity, and the vertical velocity. Measurements are also made of the positions of the controls, and all are recorded photographically.

Most investigations have been made on models in wind-tunnels. The Committee has recently built at Langley Field, in Virginia, a vertical wind-tunnel for making autorotational and spinning tests. A spinning rig is now being designed for this tunnel with which it will be possible to reproduce the conditions of a full-scale spin as far as radius, rotational velocity, vertical velocity and attitude are concerned.

A large part of the paper was devoted to a list of the factors affecting steady spin and to a description of work that has been done in their investigation. In conclusion, Mr. Weick stated that it is evident that the spinning problem is made up of a multitude of factors the relative importance of which must be determined before the solution of the problem can be considered well under way. Some progress has been made, however, for we can now measure what a spin is and calculate the inertia forces and couples. Tests have been made on about 20 of what seem the more important factors, and we are now for the first time in a position to expect accurate and valuable results from flight tests.

Fuels Discussed at Length

Operators and Refiners Tell of Requirements and Efforts Made To Meet Them

GREAT interest was taken in the final technical session of the meeting, on Thursday morning, on Aircraft Fuels, and oral discussion on the subject was prolonged to 12:30 p.m. Wesley L. Smith presided as Chairman and remarked, in opening the meeting, that the subject for discussion is one of the

SOME OF THE SPEAKERS IN THE SPINNING SYMPOSIUM

(Left to Right) Temple N. Joyce, Vice-President and General Manager, Berliner-Joyce Aircraft Corp.; Fred E. Weick, Aeronautic Engineer, National Advisory Committee for Aeronautics; Harry A. Sutton, of the Aviation Corp.; and Paul E. Hovgard, of the Keystone Aircraft Corp.

most important connected with aviation today and that we are all just beginning to realize that a big problem exists in connection with fuels. He gave the engine men and airplane operators an opportunity to be heard first, then called upon the oil representatives to present their side of the question.

In the absence of the authors, the prepared contributions by W. A. Parkins, of the Pratt & Whitney Aircraft Co., and E. W. McVitty, of the Pan-American Airways, were read respectively by E. A. Ryder, of the Pratt & Whitney company, and C. S. Kegerreis, chief engineer of the Tillotson Mfg. Co.

Fuels for Air-Cooled Engines

Mr. Parkins' paper dealt with the Relation of Fuel to Large Air-Cooled Engines. The greatest problem before the manufacturers of such engines undoubtedly is control of the cylinder temperatures in service, the author asserted. Under the best conditions of full-throttle operation, these temperatures remain from 75 to 100 deg. fahr. below the accepted limits of safety, yet poor engine installations in airplanes result in temperature increases of as much as 150 deg., and the use of fuels marketed for aviation purposes is responsible for increases of 300 deg. beyond those of normal service. Therefore particular care must be exercised in the use of the mixture control and regulation of the throttle for safe and economical performance under conditions of abnormal cylinder-cooling. Operating companies frequently overlook the possibility of lowering the gross fuel consumption as much as 10 per cent, with no sacrifice of engine reliability or performance, by changing to the best grades of fuel that are commercially available.

To meet the demand for maximum horsepower per pound of powerplant without sacrifice of mechanical efficiency, the output of the engine is increased to such a value that, with the better grades of fuel and reasonable care in operation, the engine will operate at or below its rating with an ample margin of safety. Little likelihood exists at present of the piston displacement of the conventional air-cooled cylinder being increased beyond its present maximum of about 210 cu. in. A cylinder of this size will generally operate about 50 deg. hotter than one of half its size and therefore will require a better grade of gasoline. The complications involved in distributing more than one grade of aviation fuel make it seem to Mr. Parkins inadvisable to market any other than a fuel that is suitable for use in the larger cylinder.

The compression-ratio of air-cooled engines has been kept below 5.25:1; however, if detonation is suppressed, the average reduction in cylinder-head temperature resulting from an increase in compression-ratio from 5 to 6:1 will be about 50 deg. fahr. Therefore fuel has an important relation to successful operation of the relatively large, high-output air-cooled engine suitable for military or transport use. Records of the Pratt & Whitney company show that most of the piston troubles are directly traceable to high temperatures resulting from detonating fuel.

Proposes a Standard Knock Quality

Suitable pyrometer equipment was lacking until recently and operators were without a means for determining cylinder temperatures. Most of the oil companies are without facilities for converting the relative knock value of gasoline into terms of engine performance and therefore market their products without consideration for cylinder temperatures. The Pratt & Whitney company therefore maintains a limited free service in testing gasolines. Test sam-

PARTICIPANTS IN THE SYMPOSIUM ON AIRCRAFT FUELS

(Top Row) Wesley L. Smith, Superintendent, Eastern Division, National Air Transport, Chairman; Major E. E. Aldrin, Standard Oil Co. of New Jersey; Lieut. James H. Doolittle, Shell Petroleum Corp.; and S. D. Heron, Powerplant Division, Air Corps, United States Army. (Lower Row) C. M. Larson, Sinclair Refining Co.; Dr. O. C. Bridgeman, Bureau of Standards; R. E. Wilson, Standard Oil Co. of Indiana; and Prof. G. G. Brown, University of Michigan

ples are compared with a domestic aviation gasoline refined from Gulf and West Texas crudes and blended with 2 cc. of tetraethyl lead per gallon. The quality of this fuel is no better, so far as it affects cylinder temperature, than is necessary for satisfactory full-throttle operation of the large air-cooled engines now in service. Therefore, Mr. Parkins proposes that a standard of knock quality somewhere between the knock requirements of present Navy and Ethyl Gasoline Corp. standards be adopted, and that all aviation gasolines shall meet or exceed this standard without the addition of knock-retarding agents.

Once the engine builder is assured of relatively good fuel in all parts of the Country, he will increase the engine compression-ratio or by other means still further reduce the specific weight of the powerplant. With lower temperatures goes a reduction in parts replacements, engine overhauls and general maintenance and fuel costs. The expense of producing a superior fuel may force an increase in the selling price, but this probably will be absorbed by the savings to operators in decreased fuel consumption.

Transport Company's Fuel Problem

Mr. McVitty's paper dealt with the difficulties encountered with fuel in the Pan-American Airways operations in tropical America. These include changes that occur in gasoline during transportation, handling and storage. If gasoline is stored in drums, the drums heat in the daytime and the gasoline and vapor expand, some of the vapor being forced out of the bung-hole. During the night, the drums cool and the contents contract, air being drawn in. Thus, moisture in the air condenses in the drums after repeated "breathing" and collects at the bottom. Underground tanks collect less water, although fitted with vent pipes, perhaps because of their more uniform temperature.

Evaporation losses from drums stored in the sun, which is only a temporary measure, may run as high as 3 per cent per month and often cause considerable change in the A.S.T.M. distillation range of a gasoline, though rarely enough to make any difference in the operation of an engine.

Gas formation in drums under tropical conditions is another source of trouble. Corrosion of the drums seems to have a catalytic action that accelerates the formation of gum, and a gasoline-benzol blend seems to form gum faster than gasoline. Such experiences as the company has had with cracked gasoline makes it reluctant to use this. As much as 200 mg. of gum by the copper-dish test has been found in cracked gasoline after storage for two or three months, although less than 3 mg. was present when the gasoline left the refinery.

Changes in knock rating also occur after the fuel has left the refinery, but this difference usually is not enough to cause any practical difficulty, according to Mr. McVitty, unless the knock rating of the gasoline was originally on the borderline between satisfactory and unsatisfactory fuel.

After a series of tests of samples from the various fueling stations of the company, made over a period of 18 months, the company has decided upon specifications for a kind of gasoline that it regards as desirable for its own equipment and conditions of operation. These are the Government specifications for Domestic Aviation Grade with the exceptions that the gum content be changed to a maximum of 10 mg. instead of 3 mg.; that the distillation range lie between that for Fighting Grade and Domestic Aviation Grade, and that a specification be added requiring that the knock rating shall not be greater than 5 on the scale of the Standard Oil Co. of New Jersey.

The fuels used by the Pan-American Airways produce cylinder-head temperatures of 400 to 425 deg. fahr. when one engine is throttled back and the remaining engine or engines are operated at full throttle.

It is possible to specify a gasoline that will not cause vapor lock or poor distribution for a given type of equipment under given operating conditions, according to Mr. McVitty, but the exact limits of these requirements are difficult to specify. Aircraft operators are badly in need of data on the effects of distillation range on power output and fuel consumption and will greatly appreciate the assistance of some organization technically and financially in position to supply them.

Temperature Method for Antiknock Rating

A valuable contribution to the symposium was presented by S. D. Heron, of the powerplant division of the Army Air Corps, who added considerable later information to the preprinted copy of his paper dealing with the fuel requirements for aircraft from the viewpoint of the Materiel Division of the Army Air Corps. He considered these briefly under the headings of (*a*) antiknock value, (*b*) volatility, (*c*) vapor-locking and starting properties, (*d*) gum, and (*e*) available fuels and antiknock agents.

The most important quality undoubtedly, he said, is the antiknock value. Fuel having an approximate antiknock value of 70 to 75 octane and 25 to 30 heptane is amply good for most modern commercial and military engines but for ground-boosted high-compression and high-cylinder-temperature types the Air Corps intends to standardize on an antiknock value of 87 octane and 13 heptane.

Failure of an engine as a result of using fuel of insufficient antiknock value is almost always the result of overheating of the cylinder unit. Evidence exists that the relative tendencies of fuels to knock audibly and to overheat the cylinder unit are not always equal; therefore a temperature method of rating fuels for aircraft may prove more desirable than one depending upon intensity of knock.

More Volatile Fuel Desired

Domestic Aviation Grade does not seem to be volatile enough for the minimum fuel consumption without excessive heating of the induction system and consequent power loss. Fuel-injection devices now undergoing test, with injection either into the combustion-chamber or the induction system, may allow the use of less volatile fuel than D.A.G. without power drop or distribution troubles.

A gasoline having a 10-per cent point much below 150 deg. fahr. violently accentuates vapor-locking. Even if fuel systems are improved so as to allow reducing the temperature limit below 144 deg., it is possible, said Mr. Heron, that any considerable lowering will be undesirable on account of the fuel boiling in the tanks of supercharged engines, which may reach 30,000-ft. altitude in 20 min., with virtually no reduction of temperature of fuel in the tanks. It is probable that the Air Corps specification for Domestic Aviation Grade will be modified to provide an upper limit of temperature of 167 deg. for the 10-per cent point and a maximum Reid vapor pressure probably not in excess of 6.5 lb. per sq. in. at 100 deg. fahr.

No undesirable effects from gum in cracked aviation Ethyl gasoline have been found in endurance tests in flight, although the tests were made with gasoline that was admittedly low in gum content and quite gum-stable.

Ample supplies of Fighting Grade gasoline having an approximate antiknock value of 70 to 75 octane and 25 to 30 heptane, of both gum-stable cracked and straight-run types, seem to be available. When higher antiknock values are required, the addition of tetraethyl lead and aromatics seems to be the best method. Benzol, said Mr. Heron, appears to be relatively ineffective at high cylinder-temperatures and cannot be used in concentrations much in excess of 20 per cent, because of ice formation in the induction system. Many present types of airplane develop troubles when operated on fuels containing lead, according to the speaker, but the troubles are vastly less difficult to overcome than those caused by insufficient antiknock value. Therefore, for the present, the Air Corps is requiring that super-performance engines developed for its use shall operate satisfactorily on fuel containing 6 cc. of lead per gallon.

Fuel Producers' Problems Reviewed

First presentation of the fuel producers' position was made by C. M. Larson, of the Sinclair Refining Co., who stated that the development of an improved normal fuel, with a proportionate yet reasonable increase in cost, is necessary so that engine manufacturers can offer an improved product. How far and how fast this improvement in Domestic Aviation gasoline can be made depends upon the economic distribution and availability of the product and the standardization of the aircraft-engine manufacturers' requirements.

The speaker gave figures showing that of the 22,600,000 gal. of aviation gasoline dispensed in 1929, more than 3,750,000 gal. were consumed in private flying, 15,750,000 gal. in aerial service and only slightly more than 3,000,000 gal. by scheduled transport service. These figures compare with an aggregate annual consumption of 15,000,000,000 gal. by the 26,600,000 motor-vehicles in operation.

Five groups of consumers of aviation gasoline were listed by the speaker as demanding as many types of fuel developed from five separate and distinct sources, based on the various specifications of the Department of Commerce, the Army Air Service and the Navy Department. The first four groups desire fuels having distillation range, color, doctor, acidity and sulphur specifications that are identical. The confusion arises from differences of opinion as to what method or dope shall be used to arrive at a suitable antiknock value. Grief has been added to the situation by lack of understanding as to how far a universally distributed product can be raised in antiknock value without a price increase to airports of 3 to 5 cents per gal. over the tank-wagon price for U. S. Motor Gasoline.

The first step to take seems to Mr. Larson to be to raise the gum-content limit from 3 mg. to at least 20 mg. per gal. Several gasolines having a gum content in excess of 50 mg. apparently are giving satisfactory service. By allowing refiners the larger gum-content, they will not be restricted to producing straight-run aviation gasolines, which have a low antiknock value.

The petroleum industry would welcome the working out through proper channels of a standard specification to cover one aviation gasoline having a reasonably high antiknock value, to be used for private flying and aerial service as well as air-transport operators, and perhaps one other specification to cover fuel for the Army and the Navy and those other consumers who may desire to use superchargers, all of whom find it necessary to go to compression ratios higher than 5.1:1 for air-cooled engines.

Lieut. J. H. Doolittle, of the Shell Petroleum Corp., pointed out that one of the chief points of difference between aircraft-engine fuel and ordinary motor fuel is that higher volatility is required in the former. Provision must be made for ease of starting, good distribution, freedom from vapor lock and reduction of fire hazard.

Each of these requirements demands that a certain percentage of the fuel shall or shall not be evaporated under a given set of temperature and pressure conditions, which conditions vary widely from one engine to another and with changes in atmospheric temperature. Fortunately, said Lieutenant Doolittle, the small changes in the volatility of gasoline to suit the engine do not appreciably affect its performance in the engine, but small differences in engine design, especially in the induction system, far overshadow any change made in the volatility of the fuel. The problem resolves into two phases: (*a*) study of how any given fuel will evaporate under any given conditions of temperature and pressure, and the various means of measuring these characteristics; and (*b*) practical application of these volatility characteristics and their effect on engine performance, such as ease of starting and good distribution.

Starting and Fuel-Economy Needs

For easy starting and good distribution, at least 15 per cent must evaporate at low temperature; on the other hand, vapor-locking trouble will result if the initial fractions evaporate too easily. To obtain maximum performance after the initial start and not run the carbureter at an unnecessarily rich mixture, with consequent crankcase-oil dilution, a somewhat larger percentage of the fuel must evaporate. Therefore it is desirable to have a fuel containing a small quantity of very light material and a larger quantity of medium-light material which will not require a high temperature for evaporation, so that after the initial start the engine needs only to be warmed up for a short time in order to get maximum performance.

To obtain the lowest possible fuel consumption consistent with maximum power output, all cylinders must receive a uniform ratio of fuel to air, which is particularly difficult to effect in airplane engines because of the nature of the induction systems. External heat must be kept as low as possible without liability of ice forming on the carbureter and throttle. Therefore virtually 100 per cent of the fuel must evaporate under the conditions.

Since the danger of vapor lock as well as the ease of starting depends in large measure on the atmospheric temperature, it is advantageous, asserted Lieutenant Doolittle, to base specifications concerning the lighter fractions upon this temperature and the ceiling it is desired to reach.

The ideal fuel, concluded the speaker, is one that has a sufficiently high boiling-point to avoid vapor lock and minimize fire hazard but about 20 per cent of which evaporates at the initial boiling-point; the more the hump in the distillation curve is removed without lowering the initial boiling-point, the better the starting and warming-up characteristics will be.

Knock Values of Fuels

The contribution to the fuel subject by Major E. E. Aldrin, of the Standard Oil Co. of New Jersey, was brief and concerned knock values and their determination. The difficulties met in this connection arise largely from lack of a common language on the subject and a uniform condition for test. Those who have studied the subject have found that comparison of test results on the effect of fuels in water-cooled and air-cooled engines is nearly impossible.

Most of the paper was composed of explanations of a chart compiled by Major Aldrin from test data and devised for the purpose of clarifying the information. This chart showed roughly the poorest permissible knock rating for aviation engines at full throttle and under adverse operating conditions. Various fuel blends and doped fuels were represented as to knock value on the fuels scale of the Standard Oil Co. of New Jersey, in which Esso, which is equivalent to a 50-per cent blend of benzol and Mid-Continent gasoline, is taken as zero. Various air-cooled and water-cooled engines are placed approximately opposite the figures on the scale representing the knock values of the different fuels, indicating the fuel lowest in knock rating on which they will operate at full throttle under adverse conditions.

The chart was offered for comment and criticism, Major Aldrin confessing that he can criticize it severely himself, but saying that he has not yet hit upon a better method of presenting the facts available.

Discussers Comment on Various Points

Discussion following the conclusion of the papers was concerned with various phases of the subject, participated in by R. E. Wilson, of the Standard Oil Co. of Indiana; President Edward P. Warner, editor of *Aviation;* Chairman Wesley L. Smith, of the National Air Transport; J. H. Geisse, of the Comet Engine Corp.; Prof. G. G. Brown, of the University of Michigan; E. W. Zublin, of the Texas Pacific Coal & Oil Co.; and Dr. O. C. Bridgeman, of the Bureau of Standards.

Regarding fire hazard, Mr. Wilson stated that about the only difference between gasolines is whether, at the temperature prevailing, an explosive mixture is contained in the tank above the level of the fluid. The more volatile gasolines are less likely to form an

explosive mixture in the tank than are the relatively non-volatile gasolines, because they form an over-rich mixture.

Concerning gum formation, he stated that certain anti-oxidizing or passivating agents, when added to cracked gasoline, greatly decrease the tendency to form gum during storage; in fact, cracked gasoline can be made virtually as gum stable as straight-run gasoline. In general, gum formation and loss of antiknock value go hand in hand. The copper-dish test bears no relation to gum deposit in the engine, though it shows how much gum is likely to form during storage. To determine how much gum is likely to be deposited in the engine, it is necessary to evaporate the gasoline in the absence of air. If actual gum content even approaches 40 mg. per gal., serious deposits undoubtedly will occur in the engine. However, Mr. Wilson believes that the present Army specification limit of 3 mg. is too low to permit of development of improved types of fuel at lower cost than would otherwise be made available.

Mr. Wilson also said that placing any limit as strict as 6½-lb. vapor pressure to avoid vapor lock interferes with both ease of starting and the antiknock value of the gasoline; in almost any type of gasoline, the more light ends it contains, the better is its antiknock value.

To avoid evaporation losses and condensation of moisture in storage tanks, mentioned by Mr. McVitty, Mr. Wilson suggested using either the floating roof or the breather-bag protective storage, which make possible the storage of gasoline for about a year with negligible loss.

Purely an Economic Question

President Warner said that the fuel question is, after all, an economic one; we can build engines to use almost any kind of liquid fuel and can get, say, 100 hp. for a certain unit fuel consumption, certain engine weight and certain frontal area. With a better grade of fuel we can economize further on the weight of engine and of fuel carried. It is simply a question of how much premium we can afford to pay for a fuel that will enable us to reduce dead weight and give us a lower fuel consumption per unit of weight.

Chairman Smith agreed with this statement and said that his company recently changed to a higher-priced fuel and is making more money as a result; it has less trouble with the engines and the fuel consumption has been reduced. Operators can probably get better fuel now than they can use efficiently; the next step is for the engine manufacturers to produce engines that will burn these fuels economically and efficiently.

The premium that can be paid for antidetonating fuel depends, declared J. H. Geisse, on the quantity of fuel to be carried by the planes on their hops. The value is quite different for a 1-hr. flight and a 6-hr. flight.

Referring to the effects of benzol and tetraethyl lead as antidetonating agents, he said that benzol causes an increase in cylinder-head temperature independently of detonation. A small quantity of benzol results in a considerable drop in head temperature, but as the quantity is increased, the temperature goes up. Benzol also has a low ignition-point and can be ignited without a spark with a 14:1 compression. It is essential, declared Mr. Geisse, that some standard method of rating gasolines as to detonation be found.

Professor Brown remarked concerning the low limit of vapor pressure in the Army specification that commercial airplanes seem to be able to use satisfactorily fuels having a vapor pressure in excess of 10 lb. and many companies are selling satisfactory aviation fuels with a vapor pressure as high as 11 lb. If the Army is having trouble, it must be because of some peculiar differences in the way the fuel tanks are laid out and the location of the fuel pumps.

Mr. Zublin corroborated Professor Brown's statement and asserted that vapor lock has been greatly exaggerated; certainly nothing should be sacrificed for the sake of preventing vapor lock.

Temperature Difference Causes Locking

Concluding the discussion, Dr. Bridgeman remarked that the problem of vapor lock can be stated very simply. The temperature of the gasoline in the tank as the airplane leaves the ground seems to be the controlling factor. The temperature at which vapor lock will occur decreases roughly 2 deg. fahr. for every 1000-ft. altitude. If the gasoline is at a temperature of 100 deg. fahr. when it leaves the ground, it would have to have a 10-per cent point higher than 135 deg. to prevent trouble. This will correspond to a little less than 8 lb. Reid vapor pressure.

Temperatures in the tanks of different planes vary considerably as they gain altitude, as some tanks are well insulated thermally while in others the temperature of the gasoline falls rapidly. The gasoline in the tank should be kept at as low a temperature as possible at the ground, and the tank should be in good thermal contact with the atmosphere so that the temperature will drop as the airplane gains altitude.

Hawks Speaks at Banquet

Serious and Humorous Addresses, Together with Superior Entertainment, Make Event Memorable

EVERYTHING combined to make the final event of the 18th National Aeronautic Meeting enjoyable and long to be remembered by the 180 members and guests who attended the Aircraft Banquet on Thursday evening. This was held in the spacious and handsome Red Lacquer Room of the Palmer House. An excellent orchestra furnished good instrumental music and various humorous songs. The dinner service was prompt, methodical and quiet. A surprise that was tremendously applauded was a march of the waiters bearing aloft on trays delectable creations of ice cream illuminated with electric lights concealed in the translucent bases. With these held high, the waiters formed a double line in front of the speakers' table while the orchestra rendered a suitable air.

President Warner opened the program, after the ice cream and coffee had been served, with very brief remarks introductory of the toastmaster, ending with the question, "Why introduce Bill Stout?" and the superlative of which was his use of the word "supererogation" in connection with his own function at the feast. A demand by Toastmaster Stout for a definition caused a reference to the late Noah Webster and elicited an anecdote in which the early American lexicographer put down the young lady who was sitting in his lap to correct his wife for saying that she was surprised. "My dear, you are astonished," he said, "It is I who am surprised."

Among those at the speakers' table who were introduced by Mr. Stout were Igor Sikorsky, "designer of our best-known amphibian"; Vincent Bendix, nominee for President of the Society in 1931; Frank Coffey, "one of the oldest fliers in the world"; Waldo Waterman and Mrs. Waterman, whose courage in flying to the races with a new type of machine was complimented by the toastmaster; Arthur Nutt; E. W. Stewart, Chairman of the Chicago Section; Mrs. Gladys O'Donnell, to whom someone had referred as the only "man" in a certain race who knew how to cut pylons; and John A. C. Warner, General Manager of the Society.

Frank Hawks, the former Army captain who established the aviation division of the Texas Co., was introduced by Toastmaster Stout as a pilot who is in the forefront of those who are do-

ing constructive research and experimenting in aviation. Speed in its relation to commercial aviation was his subject.

High Speed Aids Safety

While engineers have been devoting much attention to improving the safety of airplanes by providing for low landing-speeds, Captain Hawks' experience in flying high-speed planes has impressed him with the safety that comes from speed. High speed gives ability to avoid bad weather; and the ability to climb at 3000 ft. per min. means that such a climb can be continued for 500 to 1000 ft. after the engine goes dead, giving increased altitude to help in finding a safe spot to land. Captain Hawks does not minimize the desirability of low landing-speeds, but suggested that the improvement in engines and the many fine flying-fields that are available contribute to the safety that can be realized with high speed for regular mail and passenger service.

The cowling and everything that projects into the air must be exceptionally well mounted on an airplane that is to fly at 200 m.p.h or faster. The air is very "hard" at that speed and will take away anything that is not fastened on securely. The speaker told of an engine cowling coming loose at the end of one of his flights. Fortunately it did not get into the propeller, so no serious damage was done.

Freak racing planes that have no commercial possibilities are not thought well of by Captain Hawks, but he is impressed by the fast, small airplanes, some of them making a speed of 150 or 160 m.p.h. with 100-hp. engines. The slow miniature airplanes he believes to be more dangerous than high-speed planes. Non-stop flights across the continent are senseless, he now believes. It is much more pleasant and desirable to make several landings to rest a few minutes and get refreshments and weather reports.

"Senator" Ford Makes Humorous Address

One of the features of the dinner that contributed largely to its success as an enjoyable evening was the address, aptly called "Unhappy Landings," delivered by the well-known humorist, Senator Ford. His remarks included many witty thrusts against our justly famous Toastmaster, William B. Stout, his past and his product, which were enjoyed as much by Mr. Stout as by the audience. After telling the dinner gathering that during his first ride in an airplane he knew how laundry felt in a washing machine, Senator Ford launched a series of comments upon various airplanes. These were unusual in their accuracy as well as in their humor, but to be appreciated would have to be given in the words of the Senator himself.

It is hoped that Senator Ford can be introduced at some future S.A.E. function to Society members who have not heard him.

Air Races Attract Members

Several Take Part in Events and Aerial Show—President Warner Addresses Crowd on S.A.E. Day

THE 10th National Air Races, sponsored by the National Aeronautic Association and the Chicago Air Races Corp., formed the setting and the locale for much of the activity of the 18th National Aeronautic Meeting of the Society. Under the able managership of Clifford W. Henderson, general manager, and Major R. W. (Shorty) Schroeder, contest director, this year's air classic provided an exhibition of racing, stunt flying and formation maneuvers that compared favorably with similar events in the last two years at Cleveland and Los Angeles.

It is indisputable that the National Air Races each year provide a gathering of executives, engineers and pilots of all branches of the commercial aviation industry, and of officers and the flying personnel of the Army, the Navy and the Marine Corps. The sensational comeback of Casey Jones as a racing pilot on the opening day of the races was but a forerunner of the series of events that found its climax in the Thompson Trophy 100-Mile Race on Labor Day.

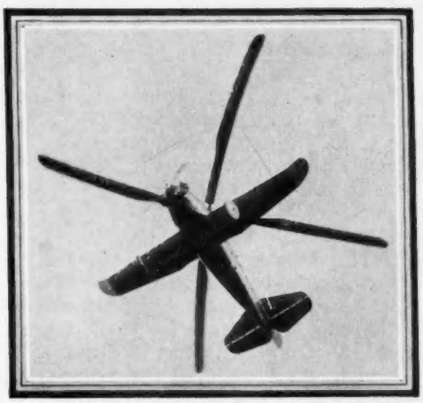
Unique Airplane Types Demonstrated

The races brought before the public the newest developments in aircraft types and construction. Three Autogiros, two of them made in this Country embodying the latest principles of design, were flown daily to demonstrate the control and landing abilities of this type of craft. Of no less interest were the exhibition flights of McDonnell's Doodle Bug, a low-wing monoplane equipped with flaps and slots and capable of being taken off and landed within a 100-ft. circle, which feat was demonstrated daily by its designer.

Waldo Waterman, Pacific Coast designer and manager of the Los Angeles Metropolitan Airport, arrived with Mrs. Waterman in a mid-wing cabin monoplane, whose wings are capable of variation in dihedral angle by being hinged to the fuselage.

Meritorious Flights of Members

A large number of prominent S.A.E. members were among the spectators and pilots. Lieut. Jimmy Doolittle gave daily exhibitions of his flying ability in the Travel Air S. Lieut. Al. Williams, another S.A.E. member, was awarded the final merit prize for flying ability during the races. His spectacular flights, including his inverted



THE GROUND MAN'S VIEW OF THE AUTOGIRO IN FLIGHT

flying around the race course and gliding to a landing on his back, stamped him as the foremost of our inverted flight masters.

Major E. E. Aldrin, Jack Whitaker, Lieut. C. B. Harper, Amelia Earhart, Herbet von Thaden and William B. Stout were among the members of the Society who flew their own planes or took part in the aerial show.

The promenade and the field held a large number of other well-known S.A.E. members who are interested and engaged in aeronautics, including two of our Assistant Secretaries; David S. Ingalls, Assistant Secretary of the Navy for Aeronautics, and Clarence M. Young, Assistant Secretary of Commerce for Aeronautics; Admiral Moffett, Edward P. Warner, Igor Sikorsky, Glenn L. Martin, Wesley L. Smith, William B. Mayo and Edward S. Evans.

The Society was also well represented on the Air Race management staff and Contest Committee by Dr. George W. Lewis and Carl F. Schory, the latter acting as chief timer for all events.

Thursday, the day of the S.A.E. Aircraft Banquet, was generously designated by Clifford W. Henderson as S.A.E. Day, and an opportunity was afforded to President Warner to address the crowd over the public address system.

The Society wishes to express its appreciation to Clifford W. Henderson and other officials of the National Air Races for their splendid cooperation in contributing their support to the success of the Society's meeting.

Airplane Design Trends Described

How Speed and Large Payload Are Obtained Told by Boeing Representative at Oregon Section Meeting at Longview, Wash.

MAJOR features of the summer meeting held at Longview, Wash., by the Oregon Section on June 28, which concluded the Section's meeting season for the year, were a 25th S.A.E. anniversary review, by F. P. Myers; motion pictures of the manufacture of seamless steel-tubing, shown by H. M. Adams; and the presentation of a paper on the Present Tendencies of Military and Commercial Aircraft Design, by R. J. Minshall, of the Boeing Airplane Co. Section Chairman H. W. Drake presided.

The 44 members in attendance were the guests of the Longview Chamber of Commerce, and arrangements for the visit were made by C. C. Humber, of the Longview Public Service Co., and Hugh Beverly, of the Standard Oil Co. Entertainment at the evening dinner meeting was provided by the Texas Oil Co. An address of welcome was made by the Hon. George S. Hays, assistant general manager of the Longview Co., who greeted the city's guests on behalf of the Chamber of Commerce, the city and his own company.

Plans for Future Meetings

Chairman Drake then announced the appointments of members to act next season on the Membership, Entertainment, Service Managers, Motor-Truck Operation, Motorcoach Operation, Aeronautic, Machine-Shop, Diesel-Engine and Student Activity Committees of the Section. Regarding plans for meetings this autumn, Mr. Drake said that a high-speed Diesel-engine session is planned for the September meeting; a service session for October, a truck-operation session for November, a motorcoach-operation session for December and a machine-shop-practice session for January. A tentative plan for the programs of these meetings is to have the committee responsible for each activity gather current data pertaining to the operation indicated by the name of the committee and then prepare a report on the subject and outline a program for the meeting. It is believed that this will result in bringing out facts, figures and views that will be more informative and representative than would a paper by one man and that such reports will be worth presenting at National meetings of the Society.

Development of the motor-vehicle from the steam car built in France by Captain Cugnot in 1760 to the present time was reviewed briefly by Mr. Myers, who also told of the influence of National organizations, including, of course, the Society of Automotive Engineers, on the phenomenal growth of the American automobile industry.

Following the showing of the three-reel motion pictures of the process of manufacturing seamless steel-tubing, the lantern was set up for projecting views of airplanes to illustrate the address by Mr. Minshall.

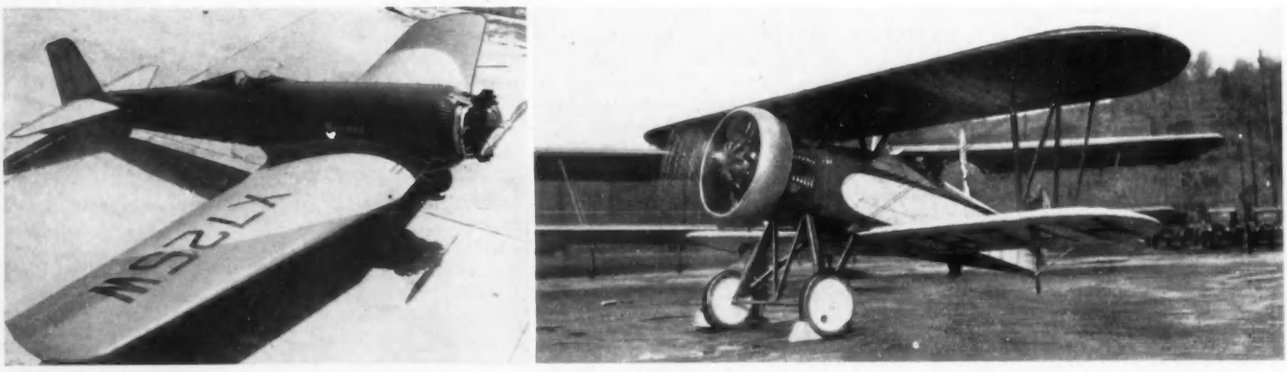
Pursuit and Mail Plane Refinement

As representative of the tendencies in aircraft design, Mr. Minshall dealt with the pursuit planes as a type of military airplane in which the utmost attention must be given to obtaining the maximum efficiency and the best performance that can be gotten from the engine, and the mail plane as representing a type of commercial craft from which the maximum performance and payload must be obtained to produce a profit in operation.

Admitting that not a great deal of progress in aerodynamics has been made since the World War, except possibly some radical changes during the last year, Mr. Minshall said that wings of thicker cross-section allow greater spar depth and have characteristics equal or superior to those of the old thin sections. Only recently, however, has the minimum drag of the RAF-15 wing-section been equaled. Similarly, no very big step in streamlining and refining the airplane was made until the last year, when the new type of ring cowling was applied to air-cooled engines, reducing the drag of a pursuit plane by nearly one-half. Also, it was discovered that the old horizontal axle between the landing wheels has much less drag than the X-type landing-gear, being 9 m.p.h. faster than the latter, which represents approximately 90 hp. on a pursuit plane flying at about 190 m.p.h.

Reduction of Structural Weight

To reduce structural weight of the mail plane so as to obtain the maximum payload-capacity, the Boeing Company used plywood-covered box-spars and a fuselage made of square section dural tubing with bolted joints. This construction resulted in giving a payload of 1600 lb. in the model 95. The latest mail plane produced by the company is an all-metal monoplane having a monocoque body with duralumin covering throughout. The skin thickness varies from 0.05 in. at the mail pits to 0.025 at the tail section. The wing covering is also of smooth duralumin, varying in thickness from the body to the tip. A great number of tests were required to ascertain the precise thickness of skin that should be used to prevent vibration or "pan-



BOEING MODEL 200 MONOMAIL AND HIGH-SPEED PURSUIT PLANE WITH RING COWL AND CROSS-AXLE LANDING-GEAR

ning" of the covering, which Mr. Minshall said was considered the greatest problem.

This latest mail plane has panel spacing of approximately 10 in. sq. and seems to be very good as regards vibration of the skin. The body is not a pure monocoque, in that it has four longitudinals extending the full length, which are computed to take all the bending stresses. The skin takes shear stresses only and prevents torsional deflection of the tail surfaces.

Full Cantilever Smooth-Skin Wing

A good reason for using the monocoque body in a mail plane, said Mr. Minshall, is that the monocoque forms the shell and side walls of the mail pit. He believes that in this latest mail plane a smooth-skin metal wing of full cantilever construction has been used for the first time. A great deal of attention was given to the wing design to avoid reversal of skin stresses when flying at cruising or high speed, so that the possibility of wing flutter would be more remote.

Riveting on the whole airplane is smooth; not a round-head rivet is to be seen. This is believed to save from 3½ to 4 m.p.h. friction drag on the wing alone. The landing-gear is retractable into the wing, the wheels swinging up and backward; about one-half of the wheel protrudes. The parasite drag of the airplane, according to the speaker, expressed in flat-plate area, was found to be about 6.65 sq. ft., as compared with 8.4 sq. ft. for the Boeing P-12 pursuit plane. This figure for the pursuit plane has been reduced, however, to 4.8 sq. ft, by revision of the landing-gear and use of the ring cowl. The frontal area of the monoplane body is considerably more than the flate-plate drag of the whole airplane, which indicates a very "clean" body.

Conditions Require Biplanes and Monoplanes

A series of a dozen and a half pusuit-plane and mail-plane models was shown in lantern slides and commented upon by Mr. Minshall, interspersed with queries from the audience, which were answered. One of these questions was whether the trend is from biplane to monoplane, to which Mr. Minshall replied that he thinks not; that consideration must be given to the design requirements for a fixed set of conditions. The low-wing monoplane meets the requirement of retracting the landing-gear. On the other hand, a monoplane was out of the question for a plane to carry machinery in Australia, a single piece of which weighed 3 tons, at an altitude of 5800 ft. In the pursuit field, the monoplane gives superior speed and the biplane greater maneuverability.

The Model 200 Monomail, said Mr. Minshall, has a gross weight of 8000 lb.; payload, exclusive of pilot and fuel, of 2300 lb.; a wing area of 555 sq. ft.; a high speed, with the best cruising propeller, of 158 m.p.h.; a cruising speed at the ground of 142 m.p.h. at 1700 r.p.m.; and cruising speed of 137 m.p.h. at service ceiling, which is about 14,500 ft. It has 220 cu. ft. of mail space and the body is 62 in. in diameter. The landing speed is 60 m.p.h. The instrument panel is equipped for blind flying.

Motor-Vehicle Cost Analyzed

Ethelbert Favary[1] Tells Northwest Section How To Calculate Cost per Mile and per Ton-Mile

THE unknown factors in Motor-Truck operation were stated by Ethelbert Favary and illustrated by diagrams at the meeting of the Northwest Section held Aug. 4 at the Bergonian Hotel in Seattle. He enumerated the various factors, including such items as overloading, high speeds over rough roads, maximum speed for long-distance operation, vibrations in the truck chassis and the like, saying that consideration must be given to all in connection with calculating costs accurately.

Preceding the technical session a chicken dinner, served family style, was attended by a large number of members and guests. A standing silent tribute was paid by those present to the memory of the late Coker F. Clarkson, formerly Secretary and General Manager of the Society. Following the introduction of guests, a short address was delivered by J. Ryan, president of the Washington Motor-Freight Association. After the dinner had been enjoyed by all, the tables were pushed back and those present devoted themselves wholeheartedly to the paper delivered by Mr. Favary.

Ton-Mile Cost the Basis of Calculation

Mr. Favary called attention to the fact that if the repair bills of one operator were $1,000 and those of another operator $500 for work on similar or identical units, it does not necessarily follow that the former operator had a higher ton-mile cost. The speaker then illustrated in detail how to obtain accurate operating-cost figures.

Overloading is one of the most common detrimental practices of the truck operator and one which will lead to the largest repair bills and subsequent failure of the truck as a whole, Mr. Favary continued. All operators do it more or less, he asserted, but the uptodate truck is designed by the manufacturer to withstand a certain load and strain. When this rated capacity is exceeded, the steel parts are subjected to a strain which exceeds their elastic limit. Rough roads and overloads cause the weight to come down on the axles with a bump, causing the steel parts to stretch or bend beyond their elastic limit, and fatigue of the steel results. From that time on, fatigue, commonly known as crystallization, continues. Sooner or later the truck breaks down and maintenance costs are increased. Vibrations in the truck are a common cause of fatigue, he continued, and tests have proved that this illness of steel is caused more often by vibration than by mere rated-capacity loads.

Fixed and Variable Costs

After commenting upon the unknown factors in cost calculation, Mr. Favary proceeded to discuss the fixed charges, six in number, using as an example a $4,000 vehicle operated under normal conditions. He described how to figure depreciation without including tires, interest on capital investment, insurance, license fees and taxes, as well as garage, administration and overhead expense. The variable charges which must be calculated to reach an accurate result consist of wages; gas, oil and grease; tires; maintenance; and repair costs, he said, the sum of all these figures being the cost of operation.

Answering direct questions after delivering his paper, Mr. Favary stated that the use of trailers with trucks for certain operating conditions is an excellent economic practice. According to accurate cost-figures supplied by trailer operators, he continued, the use of trailers will increase the payload from 50 to 100 per cent while increasing the overhead or operating costs for the truck about 20 per cent.

Following the meeting, Mr. Favary organized a class among those present which was to meet twice each week for the following six weeks. At these meetings, he was to deliver a series of lectures on common practices and data used in the automotive-engineering profession.

[1] M.S.A.E.—Consulting engineer, manager of sales promotion, Moreland Motor Truck Co., Los Angeles.

Does Not Build Engines

IN THE report of the Chicago Section meeting of Nov. 5, published on p. 691 of the S.A.E. JOURNAL for January, 1930, Harte Cooke is quoted as stating in discussion that he rode on three Diesel-engined trucks in Europe, "one being a truck with a Bosch engine and Acro system." A. J. Poole, of the Robert Bosch Magneto Co., Inc., writes

SOME OF THOSE WHO ATTENDED THE CANADIAN MIDSUMMER MEETING

that the Bosch company is particularly desirous that no impression be gained that it manufactures engines, as it does not. He believes that Mr. Cooke undoubtedly meant to say that he rode on a truck driven by an engine having the Acro system of combustion as developed by the Robert Bosch A. G.

Compression Wrongly Given

ATTENTION has been called by H. A. Reinhart, of the Ethyl Gasoline Corp., to a typographical error in the report of the Northern California Section Meeting in May, as published on p. 865 of the June issue of the S.A.E. JOURNAL. The reference to "a high-compression head with a ratio of 8.3 to 1," used on an L-head engine with which road tests were made, should read, "a ratio of 6.3 to 1." The mistake probably was due to an error in the transcript of the stenographic report.

Metropolitan Section River Trip

ON WEDNESDAY, Sept. 9, the Metropolitan Section will go on an outing trip to West Point on the Hudson River Day Line steamer Chauncey M. Depew. The object is to have an enjoyable social time and inspect the Army military academy. The cadets will be observed at drill and parade in the early evening.

The steamer leaves the Hudson River pier at 42nd street at 10:30 a.m., 129th street at 10:50 and Yonkers at 11:30 a.m. A tray luncheon will be served on board on the way up the river, and the Section members and guests will have dinner at the Hotel Thayer, West Point, at 5:45 p.m. The return trip will start at 7:30 p.m.

Arrangements for entertainment on the boat were in the hands of Sidney R. Dresser. The Day Line orchestra is to furnish music for dancing.

There are to be no technical sessions and no addresses.

Baltimore Section Program

FOR the coming season the Board of Governors of the Baltimore Section has planned a comprehensive program of monthly meetings, beginning on Sept. 24 and ending May 15, 1930. Besides the regular meetings, the Section officers plan to hold joint meetings with the Maryland Automobile Trade Association and the local motorboat association during the Baltimore Automobile and Motorboat Shows. Following are the dates and subjects chosen for the monthly meetings:

Sept. 24—Progress in Lubrication.

Oct. 15—Maintenance.

Nov. 19—Special Service Equipment.

Dec. 10—Aircraft-Engine Design, Construction and Testing.

Jan. 31—Transmission of Power; Clutches, Gearboxes and Final Drives.

Feb. 6—Baltimore Industrial Development and Traffic Control.

March 4—Diesel-Engine Types as Applied to Automobile, Marine and Aircraft Use.

April 9—Brake Design and Construction.

May 15—Trucks; Their Characteristics and Relative Capacities.

Twelve Foursomes in the Canadian Section Golf Meet

THE FIRST Annual Midsummer meeting of the Canadian Section, Society of Automotive Engineers, was held Wednesday, July 30, at the Royal York Golf Club, near Toronto. Twelve foursomes of members and guests took part in the golf tournament and 58 attended the dinner meeting following it. Through the generosity of the leading companies in the automotive industry of Canada, a truck-load of prizes was provided for the occasion. Every member and guest present therefore received one or more of the prizes, among which were several tires and leather golf bags.

This meeting was attended by many of the leaders of the Canadian automotive industry. It proved such an unqualified success that it was unanimously decided in the course of the evening that this midsummer tournament meeting should be the first of a series of annual events of the kind. A. S. MacArthur, chairman of the Canadian Section, presided at the dinner meeting and L. M. Brown, chairman of the golf tournament committee, presented the numerous prizes.

Chance M. Vought

AVIATION circles sincerely deplore the passing of Chance M. Vought, not only in the prime of life, but at the height of a distinguished career as an aeronautic engineer. Following an illness of only 20 days, death claimed Mr. Vought on July 25 in the Southampton Hospital at Southampton, Long Island. The direct cause was blood-poisoning, four blood transfusions proving ineffectual in overcoming the progress of the infection. Mr. Vought had leased a water-front villa at Southampton for the summer and was spending the season there with Mrs. Vought and their children, being apparently in good health upon their arrival.

Mr. Vought was one of the aviation industry's best-known pioneers, having been a contemporary of the Wright brothers and Glenn L. Curtiss in the early days of aviation, and was widely recognized as one of the most successful of airplane designers. At the time of his death he was president of the Chance Vought Corp., of East Hartford, Conn., builder of the Vought Corsair, the standard observation and battle plane of the navies of the United States, Japan and several other countries. He was also a director and vice-president of the United Aircraft & Transport, Inc.

Born in New York City in February, 1887, Mr. Vought acquired his technical training at the Pratt Institute, Brooklyn, N. Y.; New York University and the Ecole Polytechnique, Paris, specializing in gasoline-engine design and the allied arts. He was one of the first men to learn to pilot an airplane, being taught by Wilbur and Orville Wright. Six years after the Wrights made their first power flight at Kitty Hawk, N. C., he associated himself with Harold F. McCormick in Chicago as a consulting engineer and pilot, and in 1910 took part as a pilot in numerous aviation meetings in the East, the Middle West and in Texas. In 1912 the Aero Club of Illinois retained him as a consulting engineer, and the following year he became the aeronautic engineer and pilot of the Lillie School of Aviation, of Chicago and San Antonio. The years 1913 and 1914 found him filling the position of editor and managing director of *Aero and Hydro*, published in Chicago. This did not prove sufficiently active for him, however, and he returned to flying.

When the war broke out in Europe and the Allies were without suitable aircraft, the Mayo Radiator Co., of New Haven, engaged Mr. Vought to design a war plane which was used against the Central Powers. In 1915 he was engaged by the Curtiss Aeroplane Co., of Buffalo, as designer of the Curtiss navy plane for the British Admiralty. Appointed chief engineer of the Wright Airplane Co. in 1916, he became chief engineer of the Wright-Martin Aircraft Co., of New York City, upon the merger of those two companies in 1917. During the early war period he designed and built the PLV biplane, the Mayo, the Wright Model-V military airplane and the Simplex and Wright-Hispaño flying-boats. When this Country entered the war the Government appointed Mr. Vought consulting engineer for the Bureau of Aircraft Production. However, he continued the development of military airplanes and after the armistice organized the Lewis & Vought Corp., of Long Island City, of which he became president and consulting engineer. In this capacity he designed, built and tested the Bluebird training airplane which he entered in a Government competition and won.

In 1924 the Lewis & Vought Corp. was reorganized as the Chance Vought Corp., with Mr. Vought as consulting engineer and general manager, and concentrated its energies upon the designing and building of Navy land and sea planes combining the requirements of fighters and bombers, which resulted in the OU line of Corsairs that became standard equipment for catapulting from cruisers and airplane carriers. In 1928 Mr. Vought became acting head of the company, and last year was elected president. Early this year the company moved its plant from Long Island City to East Hartford, Conn., and has been planning the building of a line of fast commercial airplanes.

Early in 1929 Mr. Vought took an active part in the combination of the Chance Vought Corp., the Pratt & Whitney Aircraft Co., of Hartford, Conn., and the Boeing Aircraft Co. and Boeing Air Lines of Seattle, under the title of United Aircraft & Transport, Inc.

Mr. Vought was elected a Member of the Society in October, 1917, and since 1925 had been a member of the Metropolitan Section. He was also a member of the Aeronautical Society of America. He was active in the affairs of the S.A.E., having been a member of the Aeronautic Division of the Standards Committee in 1919 and 1920, a member of the House Committee in 1920, a member of the Aeronautic Committee in 1929 and Chairman of the Aircraft Professional Activity Committee and Vice-President representing aircraft engineering this year.

Harry C. Stutz

THE death of Harry C. Stutz on June 26, as a result of his failure to rally from an operation for appendicitis, removed from the automobile industry another of its true pioneers who designed one of the best American automobiles and, until his sudden demise, was on interested worker.

Mr. Stutz was born in Union City, Ind., Sept. 12, 1876, and received his education in that city. He early evinced a keen interest in mechanics and for four years conducted a small machine-shop at Dayton, Ohio, where he built automobile engines and parts. In 1903 he went to Indianapolis, where he organized the American Motor Car Co. and designed one model of the American car. He joined the Marion Motor Car Co., of Marion, Ind., as manager and engineer in 1906 and remained with that company for four years. In 1910 he was factory manager and engineer of the Empire Motor Car Co. and president and engineer of the Stutz Auto Parts Co. The Ideal Motor Car Co. was organized in Indianapolis in 1911, with Mr. Stutz as engineer and factory manager, to manufacture the Stutz car, which he designed and which competed in the first 500-mile Indianapolis Speedway race.

Mr. Stutz organized the Stutz Motor Car Co. in 1913, which built the Stutz cars for six years, and in 1919 he disposed of his interests in that company, of which he was president, and joined in the organization of the H. C. S. Motor Car Co.

Five years later he temporarily abandoned the automobile field. About two years ago he desiged a four-cylinder airplane engine and was negotiating with airplane manufacturers for its use at the time of his death.

Mr. Stutz was elected a Member of the Society in 1911.

Frederick Robertson Smith

FREDERICK ROBERTSON SMITH, chief engineer of the Armstrong Siddeley Motors, Ltd., of Coventry, England, with which he had been connected for the last two decades, passed away on June 15.

Born in June, 1882, at Kings Lynn, England, Mr. Smith acquired his technical education in the University School at London and the Technical School at Kings Lynn. Thereafter, he served as an apprentice and as an employe with Savage Brothers, of Kings Lynn, builders of commercial vehicles, for 5½ years, and as draftsman for John I. Thornycroft & Co., automobile and boat manufacturers, of Chiswick, and Napier & Son, Ltd., of London, automobile manufacturers, for 5½ years. For the next 2½ years he was chief designer and manager of Aberdonia Cars, Ltd. He then joined the Siddeley Deasy Motor Car Co., of Coventry, which later became the Armstrong Siddeley Motors, Ltd. As chief designer he redesigned the Siddeley Puma engine and the Siddeley aeronautic engine and designed the Siddeley Tiger engine.

Mr. Smith was elected a Foreign Member of the Society in March, 1919.

Glenn Hammond Curtiss

WHEN Glenn H. Curtiss died at Buffalo on Wednesday, July 23, 1930, the world at large, as well as the automotive industry, mourned the passing of a truly great and genuinely admired pioneer.

Mr. Curtiss was more than outstanding in his pioneering; he was unique. He did not restrict himself to activity on the ground, or on the water, or in the air. In all three he adventured, and in all three he excelled. Moreover, his achievements were always dual in nature. He had long been preeminent for establishing speed and other performance records on land, on water and in the air, being in each case himself the designer and the pilot of the winning vehicle.

Glenn Curtiss was born at Hammondsport, N. Y., on May 21, 1878, and received a general education in the schools of his native town. His first business venture was a bicycle shop, but he early began experiments with motor-vehicles; and, after establishing a motorcycle factory at Hammondsport in 1902, he soon was engaged in work upon airplanes, hydro-airplanes and aeronautic engines, before the aeronautic industry had more to its credit than an assortment of dreams and a few skeptically received accomplishments. As early as 1904 he designed and produced an engine which Capt. T. S. Baldwin used in a dirigible balloon, and the following year he furnished to Captain Baldwin the engine that drove the first dirigible accepted by the United States Government.

While making his initial experiments with aircraft and aircraft engines, Mr. Curtiss was by no means neglectful of his earlier interest, the motorcycle. He set a speed record for the motor cycle, riding his own machine, at Ormond Beach, Fla., in 1905. In 1907, also at Ormond Beach, he rode an eight-cylinder air-cooled motorcycle, of his own design, and established a record of 137 m.p.h., which has never been broken.

In 1907, Mr. Curtiss, together with Dr. Alexander Graham Bell, J. A. D. McCurdy, F. W. Baldwin and Lieut. Thomas Selfridge, formed the Aerial Experiment Association, which built a number of airplanes and performed various aerial experiments. During the course of these experiments Mr. Curtiss developed the ailerons for horizontal control. The third airplane produced by the Association was the June Bug, which was the first machine built under Mr. Curtiss' direction. In it he competed, successfully, on July 4, 1908, for the *Scientific American* trophy offered for the first public flight of 1 km.; this was the first prize offered in America in connection with airplane flight.

Making a flight of 24.7 miles at Hempstead, N. Y., Mr. Curtiss won the *Scientific American* trophy the following year. A little later he won the Bishop prize for a flight of 1 km. in 2½ min., and, probably as a result of winning this prize, he was selected by the Aero Club of America to represent this Country at the aviation meeting at Rheims, France, that summer. Using an airplane and engine of his own design, he won the coveted Gordon Bennett Speed Trophy at Rheims, by covering 20 km. in 15 min., 50.6 sec., thus establishing a new speed record by traveling at the rate of 46.5 m.p.h. At an air meet at Brescia, Italy, shortly afterward, Mr. Curtiss again took first prize for speed. An observer at Rheims commented particularly on Mr. Curtiss' coolness, and that was, in fact, one of his most dominant characteristics.

A flight from Albany to New York City was regarded, in 1910, as a feat of no small prowess, and the *New York World* in that year offered a prize of $10,000 for such a flight. Glenn Curtiss won the prize, piloting a biplane of his own design. In making this flight, he was the first man to follow continuously a river as an aerial highway, as well as the first to fly between two cities.

For several years Mr. Curtiss had been interested in the problem of amphibious machines and experimented for some time in an attempt to develop a hydro-airplane. In February, 1911, in an amphibious airplane of his own building, he accomplished the first flight ever made from land to water and from water to land. The following year, piloting a flying-boat of his own invention, he won a prize awarded by the Aero Club of America. To him belongs the credit for building and piloting the first plane to take off from and alight upon the water. In the two years following his demonstration of the flying-boat he introduced it to Brazil, Russia, Austria, Italy and Germany. In 1911 he was awarded the Robert J. Collier Trophy for the most signal advance in aviation during the year, and in 1912 was awarded the Collier trophy for the invention of the flying-boat. Another honor bestowed upon him was the Langley Medal, awarded to him by the Smithsonian Institution in 1916.

At the very beginning of his work with aircraft, Mr. Curtiss perceived the need for teaching young men to fly, and he established schools for this purpose at Hammondsport, N. Y.; San Diego, Calif.; Buffalo; Newport News, Va.; Miami, Fla.; and Atlantic City, N. J.

The outbreak of the war in Europe in 1914 gave a decided impetus to the demand for airplanes, and the Curtiss plants grew rapidly to meet the demand, expanding still further after the United States entered the struggle. As a result, Mr. Curtiss found himself too much absorbed in the executive end of his affairs. Accordingly, he interested John N. Willys in his plans and effected a combination of their interests, with the result that Mr. Curtiss was left free to put his energies into the experimental branch of the work which he particularly liked. He organized and thereafter centered his attention on the Curtiss Engineering Corp., a company that was devoted to experimental work.

After the armistice, Mr. Curtiss worked in cooperation with the United States Navy to develop the Navy-Curtiss flying-boats 1, 2, 3 and 4. The N-C 4 holds the distinction of being the first aircraft of any kind to cross the Atlantic, the flight being made in May, 1919.

Nearly 10 years ago, Mr. Curtiss retired from active interest in the aviation companies that bear his name. Apropos of this fact, Wing Commander Charles Kingsford-Smith and his associates, in an expression of regret evoked by Mr. Curtiss' sudden and untimely death, said: "Although his personal activity ceased some years ago, his influence lived on and will always live wherever men fly and wherever the airplane serves."

Mr. Curtiss was an honorary member of the National Aeronautical Association and a member of the Aero Club of America, the Aero Club of France, the Aeronautical Chamber of Commerce of America, the Army and Navy Club, and the Sphinx Club of New York. He was the holder of air pilot's license No. 1 in America and air pilot's license No. 2 in France.

A tribute to Mr. Curtiss was offered by F. B. Rentschler, president of the Aeronautical Chamber of Commerce of America, in the following words: "Aviation has lost one of its great pioneers in the passing of Glenn H. Curtiss. He was one of a few whose early experiments, often carried on at great odds at a time when aeronautical inventors were classed with proponents of perpetual motion, greatly aided the technical advancement of the airplane." C. M. Keys, president of the Curtiss-Wright Corp., called Mr. Curtiss "one of the great original minds in aviation"; and Rear Admiral W. A. Moffett said that "as a pioneer in aviation he contributed greatly in developing it from an impractical dream to a magnificent reality."

Perhaps Mr. Curtiss has never been better characterized than in a brief and simple expression, written years ago, in which his friend, Augustus Post, described him as "an American boy who worked his way up from the making of bicycles to the making of history."

Applicants for Membership

The applications for membership received between July 15 and Aug. 15, 1930, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

BELL, GODFREY WILLIAM, works manager, Queen's Bridge Motors Proprietary, Ltd., *Melbourne, Victoria, Australia.*

BERTRANDIAS, VICTOR E., assistant general sales manager, test pilot, Fokker Aircraft Corp., *New York City.*

BESAW, EARL WILLIAM, president, Firestone Tire & Rubber Co. of Canada, Ltd., *Hamilton, Ont., Canada.*

BRINER, EMIL AMANDUS, consulting mechanical engineer, 164 South Clinton St., *East Orange, N. J.*

BRETZ, ELLMAN O., automotive lubrication engineer, Tide Water Oil Co., *New York City.*

BREWER, HARRY C., vehicle supervisor, Bakeries Service Corp., *New York City.*

BRULL, CHARLES BERNARD, director of Citroen Laboratories, Citroen Cars Co., *Paris, France.*

BUGBEE, JAMES TAYLOR, experimental engineer, Tillotson Mfg. Co., *Toledo.*

BUTLER, OTIS W., service and consultant service, *Los Angeles.*

CRAIG, IVAN L., assistant engineer of outside plant, Bell Telephone Co. of Pennsylvania, *Harrisburg, Pa.*

DOXSEY, WALTER S., publisher, *Automotive Abstracts, Cleveland.*

ELLIS, GEORGE, consulting automobile engineer, 134 Burwood Road, *Concord, New South Wales, Australia.*

EVANS, EDWIN R., engineer, brake division, Stewart-Warner Corp., *Chicago.*

FIALA, ANTON, associate, Capitol Motor Freight, *Cicero, Ill.*

FORMANEK, EDWARD, associate of firm, E. & J. Frohlich, *Prague, Czechoslovakia.*

FULLERTON, R. T. district manager, The White Co., *Pittsburgh.*

FURUNO, LIEUTENANT-COMMANDER H., Bureau of Aeronautics of Japanese Navy, Yokosuka Naval Arsenal. *Tokyo, Japan.*

GALLOWAY, ROBERT B., production engineer, Aeronautical Corp. of America, *Cincinnati.*

GOODALL, ARTHUR RAYMOND, designer, Hudson Motor Car Co., *Detroit.*

GROSS, C. HEINZ, designing engineer, Brooks Steam Motors, Inc., *Buffalo.*

GUTHRIDGE, RALPH A., district manager, The White Co., *Portland, Ore.*

HAGAN, ALBERT W., chief engineer, Wolverine Motor Works, *Bridgeport, Conn.*

HALL, ALBERT LEO, parts superintendent, The White Co., *Pittsburgh.*

HARDING, LOWELL S., superintendent, C.A.M. 19, Eastern Air Transport, Inc., *Brooklyn, N. Y.*

HARDY, KENT S., zone parts and service manager, Cadillac Motor Car Co., *Detroit.*

HATCH, RODERIC G., advertising manager, Stewart Motor Corp., *Buffalo.*

HERZFELD, AUGUST A., fuel engineer, Vacuum Oil Co. Aktiengesellschaft, *Vienna, Austria.*

HURRLE, EDWARD C., salesman, trucks, Francis Motor Car Co., *Portland, Ore.*

JONES, EDWARD A., service manager, Yellow Cab Co. of Virginia, *Richmond, Va.*

KALLER, JOSEPH J., body draftsman, Packard Motor Car Co., *Detroit.*

KOCH, ALFRED S., vice-president and general manager, Mohawk Aircraft Corp., *Minneapolis.*

LEE, GENERAL Y. C., director general, Liao Ning Trench Mortar Arsenal, *Mukden, China.*

MCCOMBIE, ROBERT A., service manager and shop foreman, Premier Motors, Ltd., *Edmonton, Alta., Canada.*

MCNALLY, JOHN J., salesman, The White Co., *Pittsburgh.*

MESTON, ALECK W., experimental engineer, Moto Meter Gauge & Equipment Corp., *Toledo.*

MEYERS, WILLIS GORDON, layout and detail draftsman, Ford Motor Co., *Dearborn, Mich.*

MOSTING, RUDOLF HERMAN, chief engineer, manufacturers' service division, Deutsche Vacuum Oel Aktiengesellschaft, *Hamburg, Germany.*

MILLAR, DAVID, sales engineer, diesel department, J. A. Stevens, Ltd., *London, England.*

NEULAND, ALFONS H., president in charge of development, Electro-Mobile Corp., *Irvington, N. J.*

NICHOLS, EDGAR BYRON, chief engineer, Brown Instrument Co., *Philadelphia.*

ORDORICA, MIQUEL, student, International Motors Corp., *Plainfield, N. J.*

PERRIN, RENÉ, general manager, Acieries Electrique d'Ugine, *Ugine, Savoie, France.*

PETERSON, EDWARD A., draftsman, Norton Co., *Worcester, Mass.*

ROSS, ANTHONY, assistant superintendent of equipment, motorcoach division, Houston Electric Co., *Houston, Tex.*

ROSS, WILLIAM BYRON, member of research committee, Vacuum Oil Co., *New York City.*

RUBIN, LOUIS, draftsman, Federal Motor Truck Co., *Detroit.*

SPIEGEL, JULIUS F., projecting engineer, Fokker Aircraft Corp. of America, *Hasbrouck Heights, N. J.*

STORMONT, WILLIAM, lubrication and combustion engineer, Imperial Oil Co., *Vancouver, B. C., Canada.*

TROMEL, FREDERICK C., research designer, F. B. Stearns Mechanical Laboratory, *Cleveland.*

VAUGHAN, WILBUR C., chief engineer, tractor division, Vaughan Motor Works, Inc., *Portland, Ore.*

WANG, THOMAS, assistant engineer, Liao Ning Trench Mortar Arsenal, engineering department, *Mukden, China.*

WELLINGTON, FRANK E., manager, aviation division, Wyman-Gordon Co., *Worcester, Mass.*

ZEIGLER, B. F. JR., mechanical engineer, Guiberson Corp., *Dallas, Tex.*

Notes and Reviews

AIRCRAFT

Working Charts for the Selection of Aluminum-Alloy Propellers of a Standard Form To Operate with Various Aircraft Engines and Bodies. By Fred E. Weick. Report No. 350. Published by the National Advisory Committee for Aeronautics, City of Washington, 1930; 16 pp., illustrated. [A-1]

Working charts are given for the convenient selection of aluminum-alloy propellers of a standard form, to operate in connection with six different engine-fuselage combinations. The charts have been prepared from full-scale test data obtained in the 20-ft. propeller-research tunnel. An example is also given showing the use of the charts.

The Prevention of the Ice Hazard on Airplanes. By William C. Geer and Merit Scott. Technical Note No. 345. Published by the National Advisory Committee for Aeronautics, City of Washington, July, 1930; 23 pp., 11 figures. [A-1]

The reasons for the ice hazard and the ice forms have been reported in Technical Notes of the National Advisory Committee for Aeronautics and reviewed in earlier issues of the S.A.E. JOURNAL. The present report describes the experimental apparatus for observing the formation and adhesion of ice upon small airfoils and discusses, in the light of these observations, possible means of preventing such ice formation.

The following general conclusions are drawn:

(1) The adhesion of ice to a surface may be reduced somewhat by the application of certain waxes and varnishes. In the experiments described, the varnishes containing calcium stearate and calcium oleate gave the best results. In wind-tunnel tests, the adhesion was further reduced by the application of these waxes and varnishes to a thin, heat-insulating layer of rubber.

(2) The adhesion of ice is greatly reduced when the surface consists in a vehicle which carries an oil in sufficient quantity so that the surface of the vehicle is self-lubricating. The oil must be fluid at the ice-forming temperatures and should be permanent. The vehicle is vulcanized rubber of a suitable composition.

(3) Ice may be removed from the wings, struts, wires and other parts of an airplane during flight by the inflation of properly constructed pneumatic rubber members, provided these members have previously been treated with a suitable low-adhesion oil as described in (2). These rubber parts, or overshoes, contain one or more expansion tubes or compartments which are strengthened by extensible fabric. These parts are readily detachable so that they may be used only when needed.

It is expected that more technical discussion of the process of ice formation upon a moving airfoil will be presented in a forthcoming paper by one of the authors of this Technical Note.

Impacts Tests on Rubber Compression-Springs for Airplane Landing-Gears. By K. Hohenemser. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, March 28, 1930. Technical Memorandum No. 572; 14 pp., illustrated. [A-1]

Air Forces and Air-Force Moments at Large Angles of Attack and How They Are Affected by the Shape of the Wing. By Richard Fuchs and Wilhelm Schmidt. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Jan. 14, 1930. Technical Memorandum No. 573; 20 pp., 48 figures. [A-1]

Calculation of Pressure Distribution on Airship Hulls. By Theodor Von Karman. Translated from Abhandlungen aus dem Aerodynamischen Institut an der Technischen Hochschule Aachen, 1927, No. 6, Technical Memorandum No. 574; 27 pp., 9 figures. [A-1]

The above listed three Technical Memoranda were issued during July by the National Advisory Committee for Aeronautics, City of Washington.

Range of Aircraft. By C. R. Fairey. Published in *The Journal of The Royal Aeronautical Society*, March, 1930, p. 220. [A-1]

Range, or the duration, of flight has in days gone by been limited by the behavior of the engine, the limits of the load that it could lift, and refueling, the last proving that the actual life of an engine is limited to attainment. Now Mr. Fairey comes forward preaching the doctrine of clean design, the abolition of parasite resistance and the reduction of fuselage resistance to the minimum.

He explains the need for range and describes its various handicaps, such as fuel and other supplies, which vary with the type of machine and the purpose to which it is applied. Increase of range is especially necessary in commercial aviation where distance is to be considered, night landing avoided and certain strong contrary winds to be overcome.

This is a problem that confronts the designer, and it may be overcome by a compromise of the variables of structure weight, wing loading and propeller characteristics.

The Fairey long-range monoplane, Napier Lion XI engine, was designed with the sole view of maximum possible range. A description of the design and construction of the machine are given; also a detailed account of tests and an analysis of results. From these Mr. Fairey finds that there is a parasitic drag which he attributes to turbulence caused by chassis and radiator. The obvious line of improvement would be to develop the powerplant and produce a carbureter and induction system to give a lower fuel consumption. The author also points out the necessity for cleanness of design, improvement in streamline and for greater efficiency of the powerplant. The paper is followed by a very interesting discussion.

The Strength of Transverse Frames of Rigid Airships. By Hilda M. Lyon. Published in *The Journal of The Royal Aeronautical Society*, June, 1930; pp. 497 to 556. [A-1]

After a brief discussion of the recent developments in the design of rigid airships, the author presents a brilliant treatise on transverse frames, with the following conclusions: (*a*) that the distribution of the external loads applied to the frame by the main shear wires and longitudinals is affected by the distortion of the frame both in and out of its plane; (*b*) an examination

(*Continued on next left-hand page*)

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a general rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H, Miscellaneous; I, Motorboat; J, Motor-coach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

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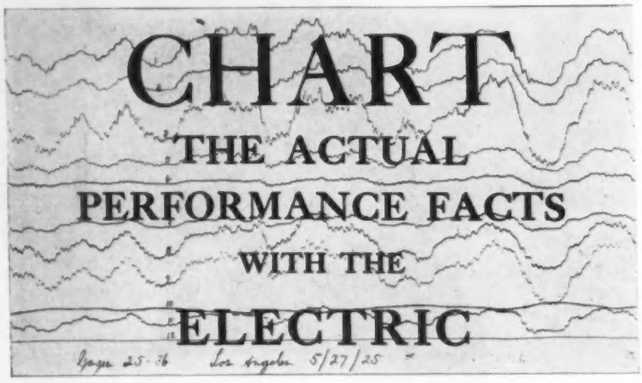

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Notes and Reviews

Continued

of the relative deflections of the points of a transverse frame may, therefore, be as important as an investigation of its strength; (*c*) the analysis of the stresses in the complete hull, with due allowances for the elastic properties of the frame and of the structure at the nose and tail, is outside the scope of this paper, although an attempt has been made to examine the possible effects of frame distortion on the loads in the shear wires and longitudinals.

The Problem of Autorotation. By H. B. Irving. Published in *Aircraft Engineering*, June, 1930; pp. 142 to 145. [A-1]

After a discussion of some of the factors affecting stability and airplane control, the author concludes that it seems to be fairly certain that any method of obtaining stability at the stall will have to go a long way in altering the characteristics of wings at the stall if it is to achieve any approach to the success of the slotted wing, which, moreover, has the advantage that, when applied to the whole of the span, it confers a considerable increase in maximum lift.

At present the designer has not nearly enough data at his disposal to enable him to be sure of obtaining satisfactory stability in the region of maximum lift by any means other than the slot.

The Cierva Autogiro Mark III. Published in *Flight*, May 9, 1930; pp. 501 to 506. [A-1]

The latest type of autogiro differs chiefly in that the rotor size has been increased, reducing its unit loading and decreasing its speed of rotation to about 125 r.p.m.

The author goes into minute detail concerning the construction features of the new machine, accompanied with drawings. Then he gives a full account of the trial performance of the craft over Southampton, England.

Creative Wing Design. By Ralph H. Upson. Published in *Aviation*, May 17, 1930, pp. 989 to 992. [A-1]

This article is a further expansion of the material from the author's recent S.A.E. paper, Wings—A Coordinated System of Basic Design, published in the S.A.E. JOURNAL, January, 1930, in which he did not set up any one rigid system of design but showed by practical example the possibilities and importance of some system for coordinating and focusing design procedure.

In the present paper the author emphasizes the importance of basic coordination between the structural aspects and the aerodynamic requirements in creative design.

Calculs de Résistance et Essais Statiques. By Léon Kirste. Published in *L'Aérotechnique*, July, 1930, p, 251. [A-1]

The structural strength requirements for aircraft differ in various countries, as do the criteria for judging this necessary qualification for airworthiness certificates. In this article, the author compares the various national regulations and discusses some of their more important characteristics.

Structural strength analyses must take account of two types of strain; external loading and internal stress. The method most generally adopted for determining loads is to evaluate them for some of the more usual cases of flight and multiply the findings by a factor of safety. The factors used in various countries are set forth, and then the author summarizes in a comparative table the methods for determining ultimate strength as practiced in France, Great Britain, Italy, Germany and the United States for aircraft designed for passenger transport. He comments particularly on the high factors of safety imposed in France in the case of wing design.

Countries which require model tests do not, for the most

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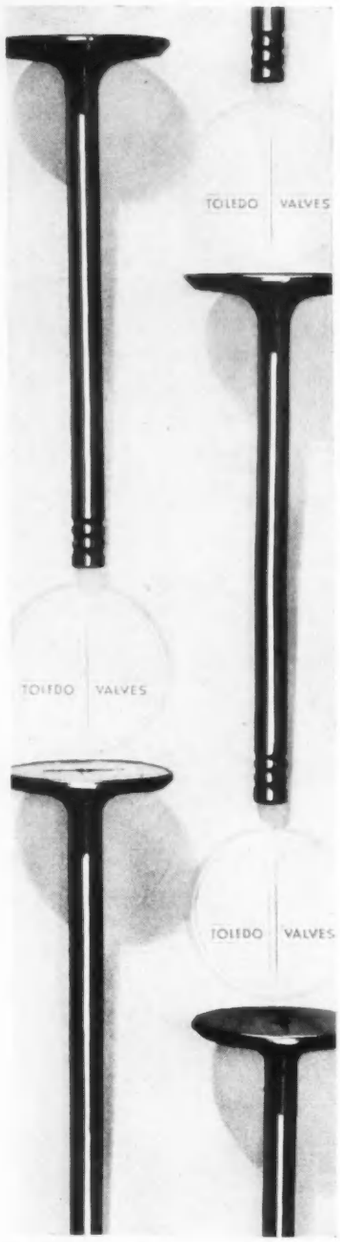

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Notes and Reviews

Continued

part, prescribe internal-stress analyses. For such calculations, the author mentions a number of considerations peculiar to aircraft which must be kept in mind, such as buckling and bending in the longitudinals of biplanes, transverse compression, buckling in compression, distortion and resistance to shear in thin sheet-metal and plywood.

In the third section of the article, the static and dynamic wind-tunnel test requirements are summarized.

Photogrammetrische Lage- und Geschwindigkeitsbetimmung des Luftschiffs LZ-127 Graf Zeppelin auf der ersten Verscuhsfahrt der DVL. By Otto Lacmann and Walter Block. Published in *Zeitschrift fur Flugtechnik und Motorluftschiffahrt*, June 14, 1930, p. 270. [A-1]

On Feb. 4, 1929, the Graf Zeppelin made a trip the sole purpose of which was to contribute to the researches of the German Institute for Aeronautical Research. It was the duty of the aerial navigation department of this organization on this occasion to develop methods by which the course made good by the Graf Zeppelin could be determined. This involved, among other things, the determination of the flying and ground speed of the ship, the amount of way made, the direction and force of the wind and the position of the craft in space.

The first part of this article describes the methods developed and explains their advantages; the second part gives the results obtained on the trial voyage.

La Normalisation des Nez de Moteurs. By J. Volpert. Published in *L'Aéronautique*, July, 1930, p. 248. [A-1]

The problem of standardizing the mounting of wooden propellers was comparatively simple, the author points out, and the necessary standard dimensions were established in France and other countries. The appearance of metal propellers complicated the problem of standard mountings, not only because of the difference in construction between a metal and a wood propeller, but because different types of propeller were introduced.

To standardize hubs for all different types of metal propeller did not seem possible; standardization efforts must center on methods of fixing the propeller-hub assembly to the engine, which inevitably involves the standardization of shaft ends. To show the difficulties that have been and will be encountered, the author describes and pictures hubs and shaft ends incorporated in French propeller and aircraft-engine design, and, after a discussion of these, suggests the construction on which it seems most feasible to concentrate.

All the World's Aircraft of 1929. Compiled and edited by C. G. Grey, editor of *The Aeroplane*. Published by Sampson, Low, Marston & Co., Ltd., London. [A-3]

This 19th annual issue gives evidence that nobody seems to be taking any chances on the approaching age of universal peace. During 1928-1929 there has been a vast expansion in the aerial fighting forces of the world. International competition in armament has been exceptionally keen.

Many of the nations have spent large amounts in subsidizing civil aviation, resulting in a remarkable increase in civil aviation of all kinds. The United States is far ahead of the other nations in this work. The terrain of the Country, barring the mountains on the east and west coasts, makes it a natural forcing ground for civil aircraft. Canadian aviation, being closely allied with that in the United States, has also made vast strides.

The book gives an accurate and astonishing picture of the world's aeronautical progress, arranged in alphabetical order of nations. The year's work of each nation in military, naval and civil aviation is written in the form of historical notes. The aeronautical publications, asso-

(*Continued on next left-hand page*)

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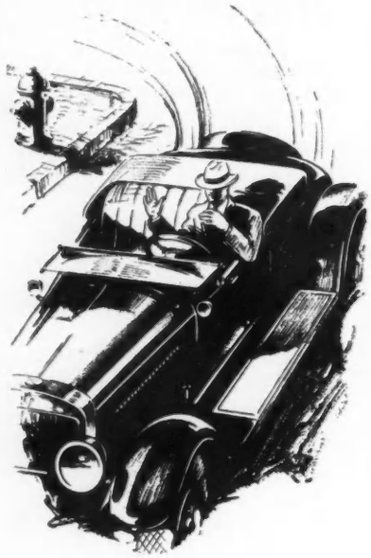

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Notes and Reviews
Continued

ciations, departments, regulations and officials of the various countries are cataloged in detail.

In addition to this storehouse of important facts, all the airplanes and airships that have been built in the last year are minutely described and illustrated. A section is also devoted to the detailed description of the parts of the various types of aeronautic engines. This is especially valuable because the introduction of several new engines has created competition in further experimental work.

The book as a whole is a remarkable piece of research in the field of aviation and is worthy of consideration.

Aeronautical Progress, 1914 to 1930. By R. V. Southwell. Published in *Aircraft Engineering*, June, 1930, pp. 137 to 141. [A-3]

Professor Southwell discusses at some length the two previous James Forrest Lectures dealing with aeronautics and comes to the conclusion that the present-day figures for efficiency show little advance on those given by Dr. Lanchester. Gain in mechanical efficiency is attributed to advances in the high-duty internal-combustion engine. From this discussion the author proceeds to give an account of the evolution of the theory answering the question, Why does an aeroplane fly? This is followed by a brief explanation of the functions of the Handley Page slotted wing.

The author holds that the new airships R-100 and R-101 are outstanding achievements in aeronautic engineering. After some remarks on this subject, he brings his lecture to a close with a plea for an elaboration of ground organization, which alone can assure the airship the future it deserves.

Advisory Committee for Aeronautics (British). By R. T. Glasebrook. Published in *Aircraft Engineering*, May, 1930, p. 105. [A-3]

The Advisory Committee for Aeronautics came into existence in England 21 years ago. This special committee was appointed by the Prime Minister and until the end of the war reported to him. The duty of the committee was to superintend the aeronautical work of the National Physics Laboratory and to advise the Navy and the War Office on the scientific problems that arose.

The committee was fortunate in its staff, which has done some brilliant work and, through its research, contributed greatly to the pioneer work in aeronautics.

In 1920 the Advisory Committee for Aeronautics was replaced by the Aeronautical Research Committee, which was granted a wider range of functions.

Aircraft Carriers. H.M.S. Glorious. Published in *Flight*, May 16, 1930, pp. 535 to 542. [A-3]

This is a rather interesting account of a visit made to the British naval ships Glorious and Furious. It is told through the medium of photographs, which are accompanied with explanatory notes.

A Three-Phase Automatic Pilot. By Dr. Waldemar C. A. Beck. Published in *Aircraft Engineering*, April, 1930, p. 80. [A-3]

This is a discussion of the design, structure and performance of the Boykow inertia frame, a gyroscopically-controlled servo-operated mechanism for maintaining an aeroplane in level flight and on a set course.

Physical Properties of Electrically Welded Steel Tubing. By H. L. Whittemore, J. S. Adelson and E. O. Seaquist. Published in the *Bureau of Standards Journal of Research*, April, 1930, vol. 4, No. 4; pp. 475 to 500. [A-3]

This investigation was made with the hope that it would enable designers of structures and machines to use welded

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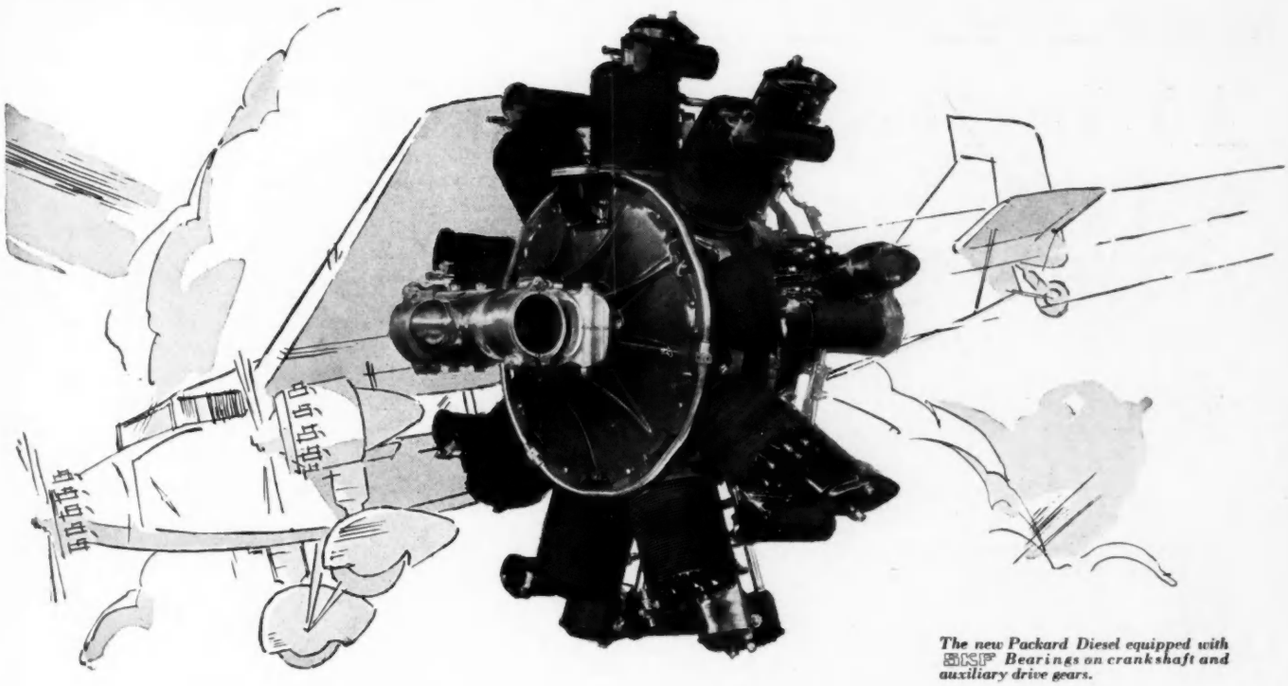

The new Packard Diesel equipped with SKF Bearings on crankshaft and auxiliary drive gears.

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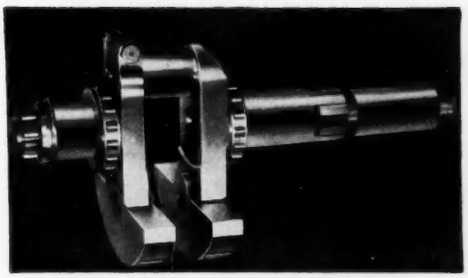
For Packard with a new world of possibilities looming ahead would not take a chance on any other than the best of all bearings.



The single throw crankshaft of the new Packard Diesel. Note the two SKF Cylindrical Bearings mounted alongside of counterweight.

The third SKF Bearing supports forward end of crankshaft and takes propeller thrust.

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Notes and Reviews
Continued

tubes economically under tensile, compressive or torsional load and internal pressure.

The conclusions were that, except in the case of swaged-annealed tubing, the properties of base metal (the metal not affected by the welding operation) can be used in determining the working stresses for different structural uses of tubing made by the process used in the manufacture of this electrically welded tubing, no allowance being necessary for the altered structure in and adjacent to the weld. The properties at and near the weld for annealed tubing are sometimes slightly lower than the properties for the base metal.

Why They Spin the Way They Do. By P. E. Hovgard. Published in *Aviation*, April 12, 1930, pp. 759 to 762. [A-3]

The conclusions of this account of the spinning characteristics of several airplanes based on flight tests were:

(1) The higher the terminal velocity of an airplane, the more difficult are the spinning characteristics.

(2) A forward position of the center of gravity is favorable at times, but is not required in all airplanes.

(3) Weights along the span should be small compared with the weights along the fuselage. The better way to reduce the precessional moment is to distribute the weights more widely vertically than to concentrate them longitudinally.

(4) A twin-float seaplane is sure to have better spinning characteristics than a landplane, while a single-float seaplane is sure to spin worse.

(5) Airplanes with high maximum-lift and low maximum L/D are the worst spinners.

(6) Lateral and longitudinal stability will eliminate flat spins but make the airplane unpleasant to fly.

(7) Frise ailerons are only slightly favorable.

(8) An increase in stabilizer area and span is the most reliable remedy.

(9) Positive dihedral, in what would otherwise be a horizontal tail, may produce results.

A 12-Course Radio Range for Guiding Aircraft with Tuned-Reed Visual Indication. By H. Diamond and F. G. Kear. Published in the *Bureau of Standards Journal of Research*, March, 1930, p. 351. [A-4]

This paper describes a radio-directive beacon or radio range, of the visual-indicating type, which has been developed by the Bureau of Standards to provide radio-marked courses at air terminals where more than four airways converge.

The radio range is similar in design to the double-modulation type, with the addition of a third amplifier-train and accompanying modulation frequency. It provides 12 equisignal zones which may be oriented within rather wide limits and made to coincide with the converging airways.

To prevent coupling between amplifier branches, special means is employed to supply them successively rather than simultaneously. This is described in detail, and the stability of the resulting system is shown to be excellent.

Applying the Radio Range to the Airways. By F. G. Kear and W. E. Jackson. Published in the *Bureau of Standards Journal of Research*, March, 1930, p. 371. [A-4]

In pursuance of the program of radio aids to flight, which was undertaken by the Department of Commerce, design and installation work has progressed under the direction of the chief engineer of the Airways Division in the application of the radio range or directive radio-beacon along the airways. To date, only the aural type has been put into

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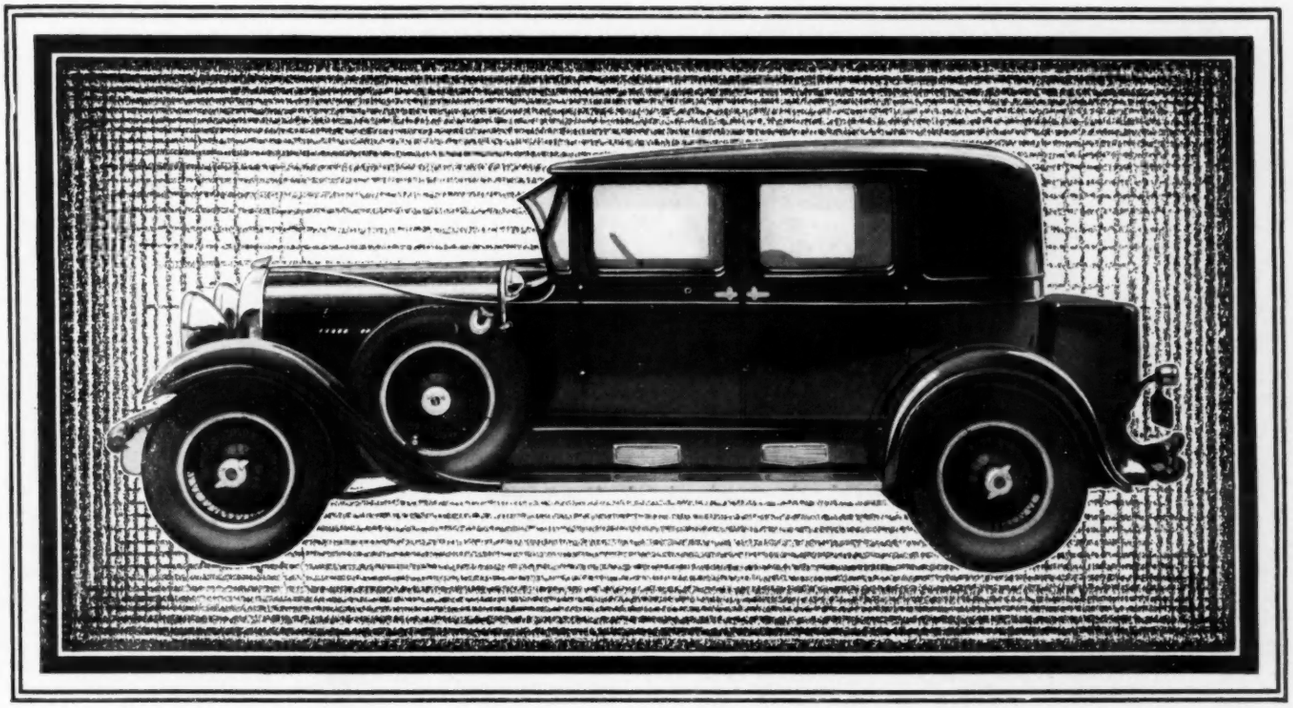
ALL AUBURN MODELS



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Notes and Reviews

Continued

routine daily operation, and it is the only type of beacon considered in this paper, in which the authors discuss the methods of adjusting the space pattern of the beacon system so that the courses shall align with the fixed airways. These beacons also need to be readily distinguished from one another and so designed that a minimum of interference is met.

By using a vertical-wire antenna in addition to the loop antennas, and varying the relative power in the two loop-antennas, it was found possible to secure virtually any array of courses desired. The radio ranges at Hadley Field, N. J., and Bellefonte, Pa., were employed in the experimental work with excellent results. The field-intensity measurements made gave space patterns that checked very well with the theoretical patterns for such antenna systems.

A Tuned-Reed Course-Indicator for the 4 and 12-Course Aircraft Radio-Range. F. W. Dunmore. Published in the *Bureau of Standards Journal of Research*, April, 1930, vol. 4, No. 4, pp. 461 to 474. [A-4]

The 12-course indicator here described is designed to enable the pilot to guide his airplane along any one of the 12 courses without confusion. It contains three reeds tuned to the three frequencies of modulation used in a 12-course radio-range.

The four-course indicator, which is similar to the two-course indicator with the exception of the operation of a shutter and color system, may be used on the 12-course radio-range. Three such indicators, with reeds tuned to match the frequency of modulation of the different courses, are necessary to cover all 12 courses.

A comprehensive description of the details of design, construction and operation is accompanied by charts and photographs.

Development of the Visual-Type Airway Radio-Beacon System. By J. H. Dellinger, H. Diamond and F. W. Dunmore. Published in the *Bureau of Standards Journal of Research*, March, 1930, p. 425. [A-4]

Research work on a radio-beacon system for use on the airways of the United States has been under way at the Bureau of Standards during 1926 to 1929. As a result of this work, a system has been developed that fulfills the requirements for course navigation on the civil airways. A directive transmitter is employed on the ground, making possible the use of simple apparatus on the airplane. A simple receiving set suffices to make use of all the radio aids provided. Visual indication is provided on the airplane instrument-board by means of a tuned-reed instrument. The pilot observes the vibrations of two reeds. On the course, the vibration amplitudes are equal; off the course they are unequal, the reed vibrating with the greater amplitude being on the side on which the airplane has deviated.

Two types of beacon transmitter are described, the double modulation and the triple modulation. The former is capable of serving either two courses at 180 deg. with each other or four courses at arbitrary angles. The latter serves 12 courses at any desired angles and is adapted for use at an airport located at the junction of a large number of airways. Reed indicators for use with the double-modulation and triple-modulation beacons are described.

Descriptions are given of the receiving set and the receiving-antenna system developed. Airplane-engine ignition shielding is also discussed.

CHASSIS PARTS

La Machine Técalémit a Vérifier de Réglage des Freins. By Henri Petit. Published in *La Technique Automobile et Aerienne*. Second Quarter, 1930, p. 33. [C-1]

Ease of operation, exactness of measurement and the possibility of making simultaneous adjustments on all four

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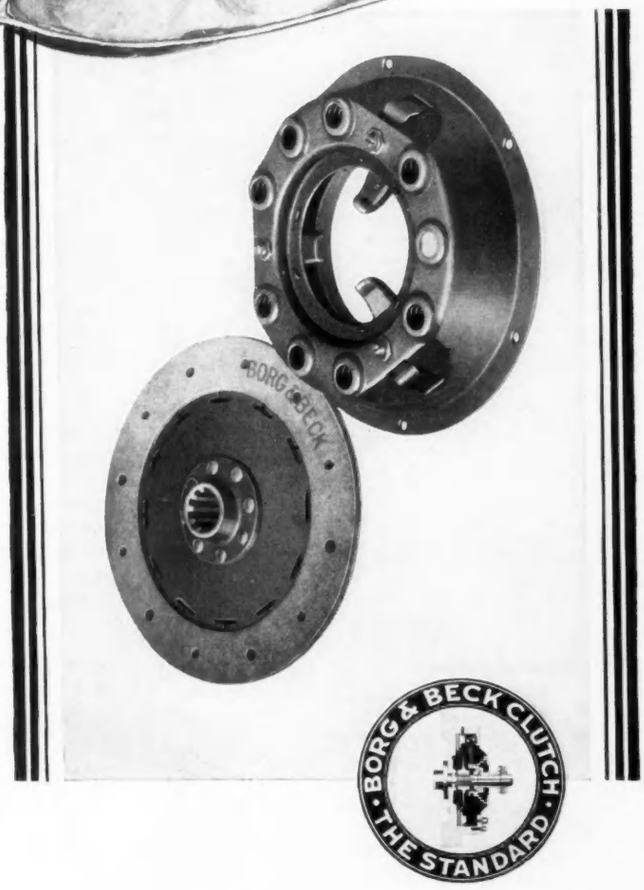
ALIKE AS TWO PEAS IN A POD . . .



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Notes and Reviews

Continued

wheels of a four-wheel braking system are the advantages claimed for the Técalémit brake-testing machine.

The machine consists of four platforms, one for each wheel of the vehicle. These platforms are carried on rollers, which are supported by ramps, the higher ends of the incline being forward. The surfaces of the platforms are designed to secure adhesion between them and the tires. The horizontal movement of the platforms is shown on a visual indicator.

The vehicle whose brakes are to be tested is run up on the machine, the four wheels resting on the four platforms. The brakes are set and the front of the car is attached to the piston of a pneumatic cylinder which tends to draw the car forward. Since the wheels are held stationary by the brakes, and the tires are prevented from slipping by the nature of the platform surface, the pull on the car tends to draw the platforms forward. The effort required to effect this movement continually increases as the incline of the runways on which the platforms move becomes more pronounced. Consequently, a time will come when the brake-linings slip on the drums and the platform bearing the wheel affected comes to a stop. Thus the braking force on any wheel is measured by the horizontal displacement of the platform which carries it.

Elaborating this general description of the machine is a detailed examination of its functioning.

EDUCATION

Applied Mechanics. By Frederic N. Weaver. Published by The Ronald Press Co., New York City, 1930; 317 pp., and index, 307 figures. Price $3.25. [D-3]

The author of this volume is assistant professor of civil engineering at Tufts College, and this textbook is based on his teaching and engineering experience. The writer expresses his belief that a course in applied mechanics should be mathematical in tone, employ a proper degree of rigor in proofs and exposition and yet, by choice of illustrations, relate the fundamental theory to the professional work that the student will later be called upon to perform. He has made the book conform to these principles.

ENGINES

Engine-Ignition Shielding for Radio Reception in Aircraft. By H. Diamond and F. G. Gardner. Published in the *Bureau of Standards Journal of Research*, March, 1930, p. 415. [E-1]

The use of highly sensitive receiving equipment on aircraft has made the problem of airplane-engine ignition shielding an important one. Ignition shielding, the authors explain, consists of so confining the electrical fields of the ignition system that no interfering signal can be set up in the radio receiving-circuits. The problem in ignition shielding is chiefly in the electrical and mechanical design of the arrangement for shielding, as it is much more difficult to secure an assembly that will not adversely affect the engine-ignition system than to obtain complete freedom from interference for the radio equipment. The article covers the Bureau's work, the shielding of auxiliary electrical apparatus and tests for the practicability of the shielding system.

High-speed Two-Stroke Oil-Engines. By P. E. Biggar. Published in *The Automobile Engineer*, April, 1930, p. 121. [E-1]

The author points out that, owing to the incomplete use of the air drawn into an oil engine, the maximum torque to be expected is somewhat less than that of a gasoline engine of corresponding size and suggests that, rather than use a larger oil engine to make up for this lower output, there is some advantage in increasing the rate of air input by a

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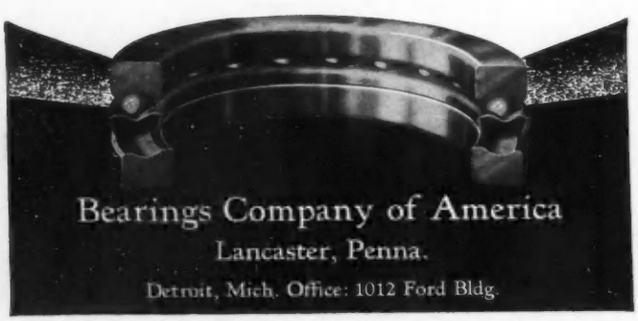

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Notes and Reviews

Continued

system of forced induction or supercharging. This the author contends is comparatively easy in the case of the oil engine, since the charge consists solely of air and therefore the degree of forced feeding is not limited by engine knocking. However, the system is used to full advantage only when it is arranged to take over the pumping strokes, so that the engine runs on the two-stroke cycle. The oil engine lends itself to such operation since its fuel is injected separately and can neither be lost with the exhaust gases nor fired during scavenging.

The article discusses the special features of the high-speed two-stroke oil-engine, which is defined as one capable of running on a non-volatile fuel of at least 0.85 specific gravity at a normal speed of at least 900 r.p.m., and the possibilities for the use of this type of engine for aircraft and road vehicles is considered.

Der Dieselmotor für Kraftfahrzeuge und seine Wirtschaftlichkeit. By Professor Wawrziniok. Published in *Automobiltechnische Zeitschrift*, June 20, 1930, p. 416. [E-1]

In concluding his general survey of the practical utility of the Diesel engine in the automotive field, the author points out five lines along which improvement should be sought.

(1) In the direct-injection engine, the development of a more compact combustion-chamber, following the example of Ricardo in the Diesel engine designed by him. This engine, incidentally, the author regards as the most hopeful indication of a bright future for the automotive Diesel. More compact combustion-chambers, he asserts, will make possible the achievement of higher engine-speeds

(2) In the antechamber type, a more careful design of the connections between the auxiliary and the working cylinder

(3) A more exact adaptation of the dimensions of the cylinders, shafts and other working parts to the pressure due to combustion and inertia, so that the weight and length of the engine may be reduced. In this connection the author expresses the opinion that the pressures generated in the normal automotive Diesel engine are greatly exaggerated; they are no greater, he asserts, than those of the modern carbureter engine

(4) Design directed against premature fuel-injection so that pre-ignition, and hence unduly high pressures during the compression stroke, may be avoided

(5) The development of more compact fuel-feeding systems, so as to avoid long fuel lines.

Among the interesting information included in this survey are tables showing comparative prices and thermal content of various types of light and heavy fuels, dimensions of some well-known Diesel engines, fuel consumption of motor-trucks powered by carbureter and Diesel engines, characteristic curves of a Mercedes-Benz motor-truck Diesel engine, and comparative operating costs of a Diesel-engined and carbureter-engined motor-truck.

Die Berechnung Erzwungener Drehschwingungen von Mehrmassensystemen, mit Besonderer Berücksichtigung der Verhältnisse bei Motorenanlagen. By Heinz Behrens. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, June 28, 1930, p. 297. [E-1]

Pointing out that the conventional mathematical methods designed to give information on the occurrence of and stress due to vibration in such systems as piston engines involve lengthy and difficult calculations, the author states as the object of his article the development of simple formulas for

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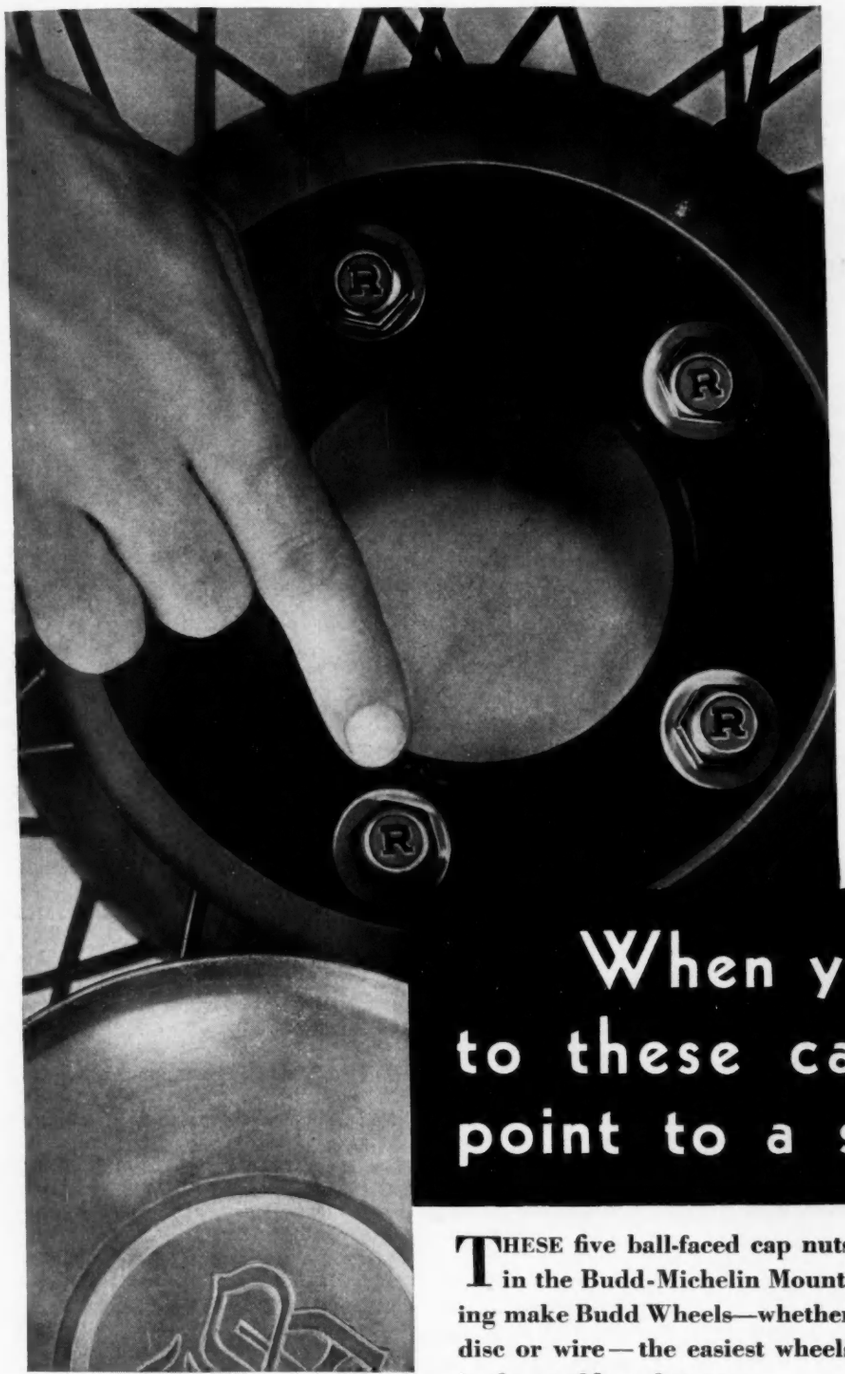

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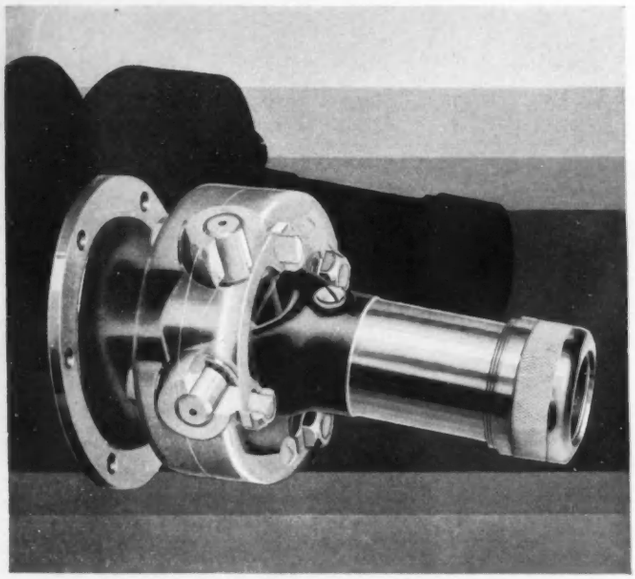

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UNIVERSAL JOINT

Notes and Reviews

Continued

this purpose. Formulas are developed with the help of which a vibrating system of any number of masses and moments can be reduced to a single equivalent mass and moment which for any given point of the system produce similar vibrations. With the proviso that the vibrating system for the most part consists of a number of like parts, which is the case in internal combustion engines, the simplified methods set forth can be used to determine the occurrence and stress of vibration.

General observations are then made on the difference that must exist between the operating speed and the critical speed in cases where the stress due to vibration does not exceed a certain determined value. A practical example is given of the use of the formulas developed and the calculated results are compared with those obtained by test.

The Resistance of Engines. By H. C. H. Townsend. Published in *Aircraft Engineering*, April, 1930, p. 83. **[E-1]**

This article is based upon experiments of the author which were presented in detail before the Royal Aeronautical Society. It gives the story of the airfoil-section ring applied to radial engines, with a suggestion for its wider use. It is accompanied with many interesting designs and illustrations.

MATERIAL

Fuels and Dopes for Aircraft Engines. By Dr. A. E. Dunstan and Dr. F. B. Thole. Published in the *Journal of The Royal Aeronautical Society*, April, 1930, p. 329. **[G-1]**

The periodical scares regarding the possible world famine in petroleum encouraged extensive experimentation to discover substitute fuels. This resulted in better refining methods, doubling the gasoline supply by cracking, and the extraction of gasoline from natural gas. So today the world faces an overproduction of that commodity.

Dr. Dunstan pleads for closer cooperation between engine designers and petroleum technologists, although the producer, from the anti-detonation point of view, would always be faced with the problem of producing a better fuel; for cooperation among the fuel producers of the Country to produce a standard fuel and to agree upon a standard method of comparison with other fuels.

Much emphasis is placed upon the importance of cracked fuel whose antiknock value is possibly superior to that of benzol, and the need for research with cracked gasoline to reduce the gum bugbear.

The author suggests that for normal purposes hydrocarbon approaches the ideal metallic dope.

There is discussion at the end of the paper by Messrs. Pye, Foord, Hynes, Taylor, Evans, Bramson and Stanfield.

National Metals Handbook, 1930 Edition. Published by the American Society for Steel Treating, Cleveland. **[G-3]**

This Metals Handbook, first published in September, 1928, is now presented to industry in revised and enlarged scope. It is a comprehensive volume of concise information on the metallurgical practices pertaining to the manufacture, treatment and uses of metals. The material has been prepared from sources believed reliable and by men of high technical standing.

MISCELLANEOUS

Use of X-Rays in the Aeronautical Industry. By J. T. Norton. Published in *Aviation*, June 28, 1930, p. 1261. **[H-1]**

Although the builders of aircraft have not employed X-ray methods to any extent, Professor Norton feels confident that they have a field of application in the materials and parts of which aircraft are made. Certain defects, such as blowholes in castings, inclusion of foreign materials, shrinkage and cracks, are readily discovered by X-rays. This process is known as radiography. The X-ray is also found

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The phrase "a firm foundation" has been applied to buildings and lives. But in the Clayton & Lambert Manufacturing Company it is associated with metal stampings. For these stampings, as they leave our plant day by day, clearly and accurately reveal the character and ability of the men who made them.

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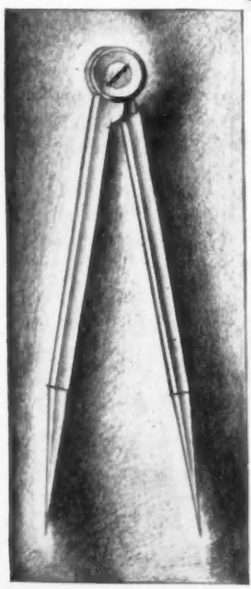

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Notes and Reviews

Continued

to be extremely valuable in detecting flaws in welds and forgings.

The use of this method of inspection has been retarded by the cost and the lack of portability of the equipment. The author asks that the cost be regarded in the light of insurance against failure. In view of the present experiments upon portable equipment, he sees a great future for radiography.

Engineering Kinetics. By William Griswold Smith, M. E., professor of engineering drawing, School of Engineering, Northwestern University; formerly associate professor of kinematics and descriptive geometry, Armor Institute of Technology; author of Practical Descriptive Geometry. Second Edition. Published by the McGraw-Hill Book Co., Inc., New York City, 1930. [H-1]

The revolutionary changes in machine design, notably in the design of gears of all varieties, made it imperative that this textbook should be revised.

Besides rearranging the order of presenting the subject, the author has incorporated recent developments in the field. At the close of each chapter is given a list of problems having real engineering value which cover the essentials of the chapter. These lists should be of great assistance to the student in reviewing and to the instructor in making up periodic quizzes and final examinations.

This textbook should be of outstanding importance to the engineer student because the author has used as his chief source of material industrial literature existing in catalogs, bulletins, handbooks and magazines.

The subject matter has been limited to the amount that can be successfully covered in the time allotted by most engineering schools.

The National Physical Laboratory Report for the Year 1929. Published by His Majesty's Stationary Office for the Department of Scientific and Industrial Research, London, 1930. [H-1]

Many interesting pieces of research have been carried on in the engineering, metallurgical and aeronautic departments, for example, the mechanical properties of materials at high pressure; the creep in alloys at high temperature; research on spring steel and chains; the toothed gear and its important influence upon design; the experiments on the reduction of head resistance and securing adequate stability and control; also the designs of fins and controls.

The results of several of these experiments are evident in the Schneider Trophy, the R-100 and the R-101.

Mechanical Engineers' Handbook. Third Edition. Lionel S. Marks, editor-in-chief, professor of mechanical engineering, Harvard University. Published by the McGraw-Hill Book Co., Inc., New York City, 1930. [H-3]

This handbook was prepared by a staff of specialists and is intended to supply both the practising engineer and the student with a reference work that is authoritative in character and covers the field of mechanical engineering in a comprehensive way. Special effort has been made to secure accuracy and to ensure that the subject matter does not embody solely the practice of one individual but is truly representative.

Die-Casting Practice. By Marc Stern, M. E., manager, Die-Casting Division, A. C. Spark Plug Co. Published by the McGraw-Hill Book Co., Inc., New York City, 1930. [H-5]

This is the first book devoted to die-casting and represents an endeavor to fill the gap in the information concerning that important branch of foundry practice. It is intended, not only for those directly connected with the industry, but especially for those interested in the use of die-cast parts. The application of die-casting, the princi-

(Continued on next left-hand page)

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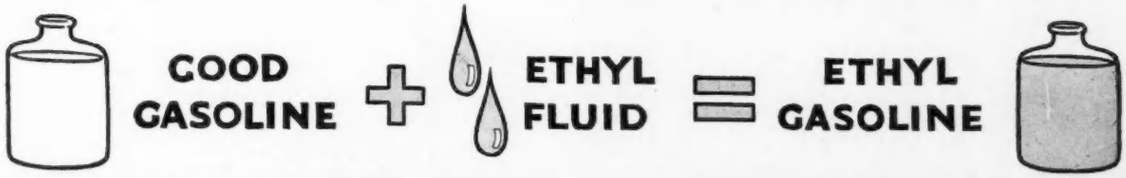

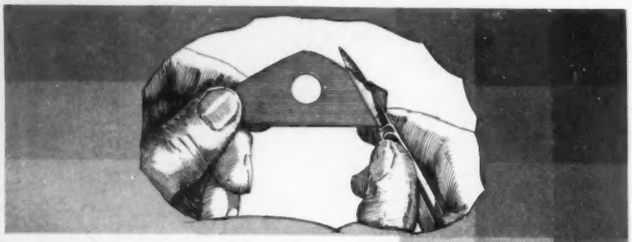

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Notes and Reviews

Continued

ples of design, the limitations and possibilities of many alloys in use, and the finishes applicable for such alloys are some of the factors of vital importance in the intelligent utilization of a comparatively new process which are ably handled.

The book may also prove of value to engineering students, a large number of whom will sooner or later come into contact with the design of die-casting.

Scientific Management in American Industry. By The Taylor Society, H. S. Person, editor. Published by Harper & Brothers, New York City. [H-5]

This treatise is an attempt to give a picture of the progress of scientific management and its influence in American industry today. It is a compilation of articles written by specialists in their own branches of management.

The priceless contribution that Frederick W. Taylor made to American industry is duly considered. The way in which his philosophy has spread over the civilized world and the progress that scientific management has made in the hands of his disciples is remarkable. This influence is evident in the increased application of intelligence to the day's work. As a result, working conditions, production and industrial relations have been radically improved.

The members of the Taylor Society have made extensive studies in management and conducted successful research in administration, merchandising and selling, clerical operations, production and personnel. One of the results of this research is the establishment and maintenance of standards.

Special consideration is given to the influence of Mr. Taylor's philosophy in the field of industrial relations. This is accomplished through the citation of specific cases. Thus did Taylorism prepare the way for the application of scientific methods in industrial relations and personnel management.

PASSENGER CAR

Montlhéry et les Essais Automobiles. By Pierre Prévost. Published in the *Journal de la Société des Ingénieurs de l'Automobile*, March, 1930, p. 941. [L-1]

Are systems of automotive testing as practised currently nothing but "scientific organizations of error"? The author does not subscribe to this cynical characterization, which he quotes as the opinion of a contemporary French automotive manufacturer, but in this discussion of vehicle testing, particularly of Citroën methods, he voices a grave warning against the possibilities of error which give rise to unjustifiable and misleading conclusions. Three sources of error analyzed are (*a*) instruments themselves, or the methods with which they are used, (*b*) operators or (*c*) the conditions, such as atmospheric or physical environment, under which the tests are made. Most serious of all are the misapprehensions that arise when the tests made are not applicable to the qualities which they are expected to measure.

Is automotive engineering an art or a science? is another question which the author propounds. Defining science as that dealing with measurable elements, he states that automotive engineering, while not yet wholly a science, is rapidly advancing to that goal. As for artistic aspects of automotive engineering, that is, the realization of beauty of form of body, chassis and engine, he points out that beauty in machinery, as in other things, is only the result of perfection, of harmony and of adaptation of form to usage, and that in its achievement certain precise and indisputable results can and must be found.

In the course of his discussion, the author lists testing instruments and analyzes the methods and personnel for their use. He mentions among the factors that are not susceptible of exact measurement by instruments as yet developed, suspension, roadability and riding comfort. He

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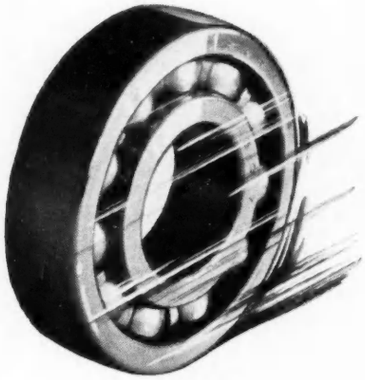
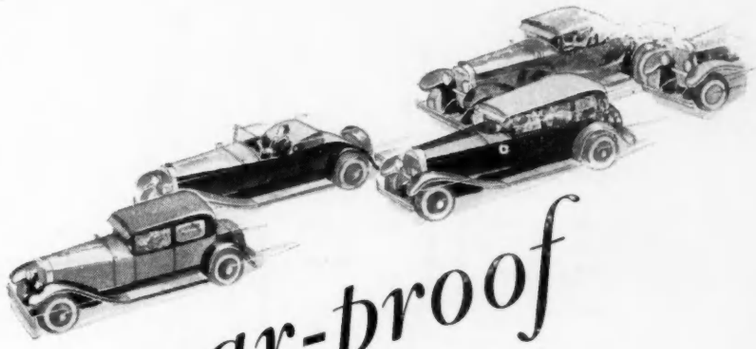
For the clutch pilot of Hudson *and* Essex





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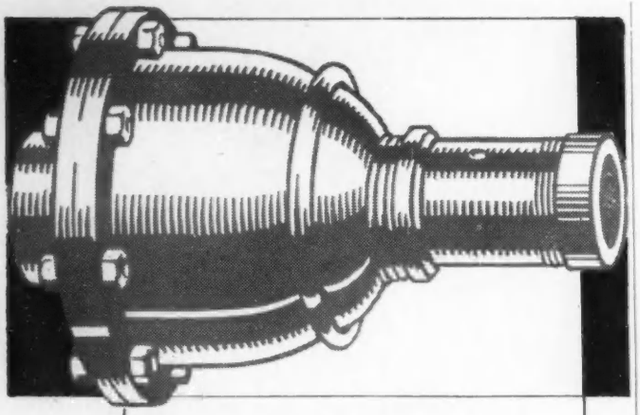

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Notes and Reviews

Concluded

appraises the value of the open road and of guarded courses in testing, and discusses the assembling and interpretation of test results, their value to all departments of an automotive organization, and the influence of American practice.

My Automobile—Its Operation, Care and Repair. By Harold F. Blanchard, M. E., technical editor of *Motor*. Second Edition. Published by the Scientific Book Corp., New York City, 1930. **[L-2]**

This book is particularly intended for those who desire to make minor repairs and adjustments on automobiles. It is especially suitable for students and to all those entering the automotive industry, including automobile salesmen, accessory storekeepers, automobile mechanics and the like. It describes the care and operation of all types of automobile and gives step-by-step instructions for finding and curing troubles of every description.

Development of a Recording Accelerometer. By Bernard J. Strouse and J. Canfield Marsh. Published in *Engineers and Engineering*, May, 1930, p. 109. **[L-3]**

This paper, which was awarded first prize in a competition of student members of the American Society of Mechanical Engineers, Philadelphia Section, describes the development and use of an accelerometer that will measure the performance characteristics of an automobile while accelerating through the gearshift range.

The development of the apparatus, the procedure for test runs and the calibration and interpretation of results are discussed fully with the aid of numerous diagrams. The authors conclude from their study that (*a*) it is entirely feasible to measure directly the acceleration of a car through the gearshifts; (*b*) the short-period pendulum-type of indicator has proved to be most suitable for this purpose, because it is simple and self-contained, responds quickly, records continuously, and works well on any ordinarily level street; and (*c*) records obtained with this type of indicator reveal, directly and conveniently, the most interesting performance characteristics of an automobile.

TRACTOR

Das Problem der Feldkraftmaschine in der Landwirtschaft. By Dr. Martiny. Published in *Automobiltechnische Zeitschrift*, June 20, 1930, p. 420. **[M-1]**

Farms on which tractors are used comprise only 15 per cent of the total farm area of Germany, according to the figures quoted in this article. Two reasons are advanced for this restriction: First, present-day tractors are not thought to be adaptable with sufficient ease to enough different types of farm work; second, they are said to be too large to be used economically on small farms. Even should the smallest tractor available, that of 25 to 30 hp., be used on every farm whose size justified it economically, still only 20 per cent of Germany's farm land would be motorized.

In tracing the development of farm tractors, the author dismisses the steam-powered type as entirely too large for the purpose, and the electric-powered as impracticable from the viewpoint of power source. To the internal-combustion engine is reserved the ability to make the tractor a useful farm tool.

Two avenues of progress are open to the promoter of farm motorization: First, the tractor might be made more easily usable for work for which teams and men are still being used, for chopping and harvesting such crops as potatoes and turnips, as well as for the task to which it is now for the most part devoted, plowing; second, the tractor should be made a real competitor of the draft animal by lowering its purchase price and operating cost and increasing its reliability. Mention is made of the possibility of reducing fuel costs by the use of low-volatility fuels, but the impression is given that the advantages of economy so gained might be offset by operating disadvantages. The possibility of making tractors available to small-farm owners by some system of community purchase is also mentioned.

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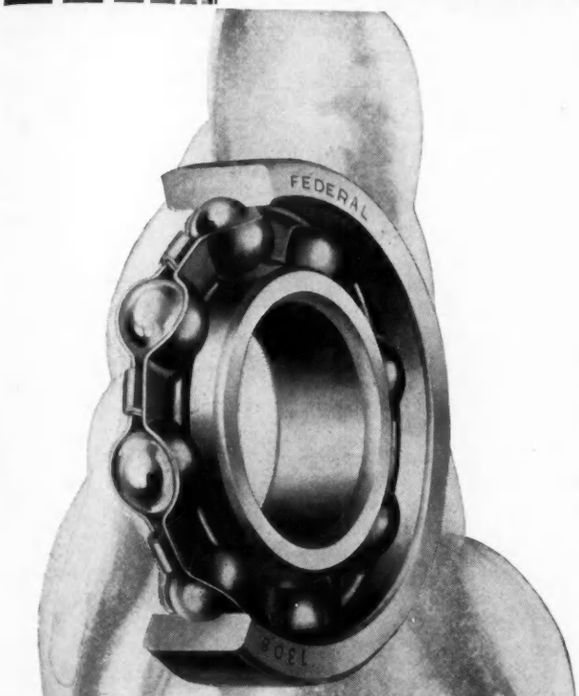

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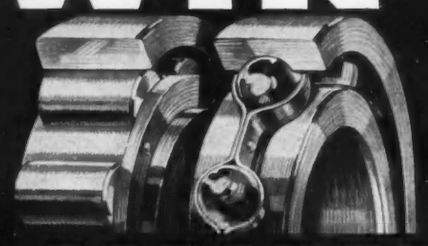
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Personal Notes of the Members

President Warner Speaks on Poles

Commander Byrd's Antarctic explorations, his and Dr. Wilkins' aircraft flights across the North Pole and present scientific expeditions to Greenland have focused world attention on the lands of the polar regions for their possible importance in future aircraft routes. A round-table discussion on The Political Aspects of Aerial Navigation was conducted by Edward P. Warner, president of the Society, at the Institute of Politics in Williamstown, Mass., in August.

Speaking on the subject, Mr. Warner said that, before getting into an argument about the possession of lands in the polar regions, it would be well to find out if there is anything to argue about. Until very recently, no very energetic efforts have been made by the nations to utilize those lands, but the development of aircraft has changed the conditions. Although the meteorological and other conditions do not seem to make commercial flights across the polar regions immediately possible or probable, certain strategic islands and other land areas may well have political importance in the near future. Mr. Warner cited as an example Swan Island off the coast of Honduras, which was ignored until recently but is now of real importance as a possible landing place in Caribbean flying. The United States Navy round-the-world fliers a few years ago found much of the Arctic region, across which it is now proposed to chart a flying route between England and the United States, nothing less than an "aviator's hell."

Major E. E. Aldrin, also a member of the Society, speaking at another session, gave an amusing account of some of the difficulties the private aviator meets in flying in Europe because of passport visas and other frontier formalities.

Col. Charles A. Lindbergh was introduced by Mr. Warner and spoke briefly on the great need for standard aviation regulations among the nations, particularly with reference to commercial air-transport in the Western Hemisphere. Rules and the forms to be filled out should, as far as possible, be uniform, he said, and governments and competing airlines should cooperate for the greater development of aviation.

Announcement has been made by Clarence M. Young, Assistant Secretary of Commerce for Aeronautics, of the appointment of **Richard C. Gazley** and **Stanley S. LaSha,** consulting aeronautical engineers of the City of Washington, as chief and assistant chief, respectively, of the engineering section of the Aeronautics Branch of the Department of Commerce. Both of the new appointees previously served in the engineering section of the Aeronautics Branch before engaging in consulting engineering work. **Kenneth M. Lane,** former chief of the section, resigned recently.

H. D. Black is a student in the junior engineering course with the Buda Co., of Harvey, Ill. He was until lately a student at Purdue University.

Lynn V. Blankman recently became a consulting engineer with the Bendix Aviation Corp., at Los Angeles. His previous connection was with the Fokker Aircraft Corp., in New York City.

Frank G. Born has become a member of the engineering staff of the Delco Products Corp., of Dayton, Ohio. Prior to accepting this position he was chief engineer of the automotive equipment division of the Wahl Co., of Chicago.

Aaron D. Brooks is now a student engineer with the Ingersoll-Rand Co., in Phillipsburg, N. J. He was until lately a student at the University of Illinois.

George E. Bussiere, a former student at the University of Detroit, is now an aeronautic engineer in the Stout Engineering Laboratories, at Dearborn, Mich.

J. A. Callahan has relinquished his post as factory manager of the Curtiss Aeroplane & Motor Co., Inc., of Buf-

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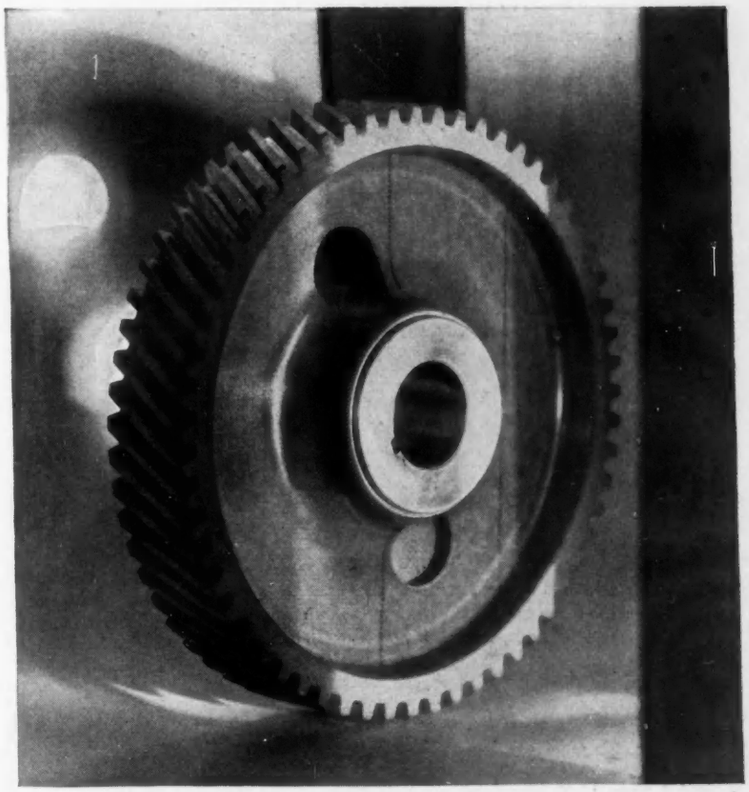

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Personal Notes of the Members

Concluded

falo, and is now connected with the Briggs Mfg. Co., of Detroit.

P. A. Collins has recently become sales manager of the Muncie Products Division of the General Motors Corp., at Muncie, Ind. His previous connection was as engineer with the Bendix Brake Co., of South Bend, Ind.

Thomas B. Davies has recently been made district sales manager for the Republic Steel Corp. at Buffalo. He occupied a similar position with the Central Alloy Steel Corp., of Massillon, Ohio, prior to his acceptance of his present position.

Sherman M. Fairchild, of the Fairchild Aviation Corp., has been elected to the board of governors of the Aeronautical Chamber of Commerce of America to succeed C. S. Reed, resigned. **William P. MacCracken, Jr.,** former Assistant Secretary of Commerce for Aeronautics, is the representative of the Aeronautical Chamber of Commerce on the Aviation Advisory Board of the City of New York.

Frank P. Freeman has been appointed automotive engineer in the lubricating department of the City Division of the Standard Oil Co. of New York, with headquarters in New York City. His previous connection was as superintendent of bus maintenance of the Public Service Corp. of New Jersey.

Moises Gabay, a former industrial engineer at Buenos Aires University, Buenos Aires, South America, is now serving the Keystone Aircraft Corp., of Bristol, Pa.

H. I. Gall, a former student at the Ohio State University, is now a student at the River Rouge, Mich., plant of the United States Gypsum Co.

Fred W. Heckert has resigned his post as associate in the V. G. Apple Laboratories, at Dayton, Ohio. He was recently appointed chief of the aircraft fuel systems unit of the Powerplant Branch of the Army Air Corps, Materiel Division, with headquarters at Wright Field, Dayton.

Walter H. Hinz has been promoted from the position of draftsman, which he held with the Wisconsin Motor Co., of Milwaukee, and is now chief draftsman with that company.

Glen H. Hurd, a student engineer at the Fort Wayne, Ind., works of the General Electric Co., was previously a student at Ohio State University.

Forrest L. Johnson recently became associated with the Westinghouse Electric & Mfg. Co., of Mansfield, Ohio, as a member of the tool engineering division. His previous connection was as a tool and die designer with the National Cash Register Co., of Dayton, Ohio.

A. C. Koenig, a former Ohio State University student, recently accepted a position as designer with the Goodyear-Zeppelin Corp., at Akron, Ohio.

Hans W. Lindemann has left this Country, where he was employed as a designing engineer for the Illinois Steel Co., of Gary, Ind., and is now employed by the Nationale Automobil Gesellschaft, of Berlin, Germany.

G. Albert Lyon, former president of the Lyon Cover Co. of Detroit, has sold his business and is now a resident of Asbury Park, N. J.

Guerard Mackey, a former student of the University of Illinois, is now engaged as mechanical engineer in conveyor work with the Grasselli Chemical Co., at East Chicago, Ind.

William G. Mayer, who has until recently been assistant manager of the associated products division of the J. G. Brill Co., of Philadelphia, has become a sales engineer for the Brockway Motor Truck Corp., in New York City.

Alexander McLeod was recently appointed district manager of the Sunset Pacific Oil Co., of Portland, Ore. His previous connection was with the Union Oil Co., of Oakland, Calif., for which he was a lubrication sales engineer.

J. Paul Miller, having resigned as designer for Duesenberg Bros., at Indianapolis, has accepted a similar position with the Studebaker Corp., of South Bend, Ind.